INSTITUTE OF
PAPER CHEMISTRY
Appleton · Wisconsin

PRODUCTION AND INTENSIVE MANAGEMENT OF GENETICALLY IMPROVED ASPEN

Project 3250

Report Two

A Progress Report

to

MEMBERS OF GROUP PROJECT 3250

February 13, 1976

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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Abitibi Paper Company, Ltd.

Blandin Paper Company

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

PRODUCTION AND INTENSIVE MANAGEMENT OF GENETICALLY IMPROVED ASPEN

SUMMARY

During 1975, the crossing program emphasized the production of large numbers of seeds and seedlings from a relatively few promising hybrid crosses. Availability of pollen and female flowers influenced the types of crosses made. "Canescens x bigtooth" hybrids received the most emphasis with the result that 168,600 seeds of this hybrid type were produced. Progress was made in simplifying nursery seedling production techniques as the result of the development of a muslin seedbed covering procedure. One interesting and extremely important aspect of the crossing program was the flowering of an artificially produced tree believed to be a tetraploid (4_n_). The tree turned out to be a male and, when the pollen was applied to a normal diploid (2_n_) female, the seedlings produced by the cross were triploid (3_n_), confirming the tetraploid nature of the artificially produced tree.

New measurement data collected on hybrids that are being fertilized and irrigated confirm earlier observations that hybrids can be expected to respond more to fertilization than the native sucker stands. Fertilization appears to have increased volume growth, an average of 50 to 60% (ST-II and ST-III) over a five-year period. Seven years of measurements (Trial ST-IV) demonstrated an approximately 30% volume growth increase has been obtained as the result of fertilizing a six-year-old aspen sucker stand in which soil moisture is often below optimum in July and August.

Early growth and survival of conversion plantings continue to look very promising. The results of the several trials under way seem to indicate that,

when hardwood stands with a minimum of underbrush are harvested by techniques that utilize a high percentage of the available wood and planting occurs the first spring after harvest, 80-90% survival and average heights of 6 to 7 feet can be expected after three growing seasons. The 23-acre Michigan DNR conversion planting averages 4.8 feet (5.3 feet for the better materials) and 95% survival after two growing seasons.

An economic analysis of the planting of hybrid aspen was run, based upon growth rates of triploid hybrids growing on Vilas fine sand. Rotation ages of 15 to 18 years can be expected to result in rates of return of 6.0 to 6.5%. Total volume production from six 15-year rotations or five 18-year rotations (90 years) was estimated to be a total of 22,800-24,800 cu.ft./acre. Total volume production from red pine growing on Vilas fine sand was estimated to be 12,960 cu. ft. (two 45-year rotations) and rates of return from growing red pine for fiber were estimated to be 5.0 to 5.5%.

INTRODUCTION

During the past five or six years the paper industry has repeatedly stressed in its public relations releases the renewable nature of its fiber resources and the favorable influence of good forest management and vigorous tree growth on air and water quality. Ironically, it appears that this PR program may be working to the paper industry's disadvantage. Wood, particularly our lower quality wood resources, are being investigated by a diverse group of industries as a future renewable resource for their use. Investigated uses of wood and wood/bark mixtures include use as fuel, as a plant growth media, landscaping mulch, soil conditioner, cattle food, cattle bedding, poultry bedding, particle and insulation board, and as a sugar source for the production of protein and such chemicals as alcohol.

A number of the above proposed uses of wood and wood/bark mixtures have considerable potential. Employment of such material for its fuel value appears to be <u>the</u> use that in the long run will have the greatest impact on the cost and availability of this source of fiber for use by the pulp and paper industry. The widespread increased use of wood as a fuel is illustrated by a recent article in the Washington Post by Erik Eckholm. Developing countries are often pictured as a future source of fiber when, in fact, countries like China and India, because of population increases and recent major increases in fuel costs, are faced with ever increasing wood shortages. In Nepal, firewood prices have tripled in the last two years. In Niger, the average family spends one-fourth of its income on firewood. Foraging for firewood until recently had been a way of life in underdeveloped countries while in India, for example, special mobile guard squads have been formed to arrest those poaching fuel in National Forestry Reserves. From China it is reported that commune plantations are sometimes uprooted at night for fuel soon after they are planted.

The continued scavenging for fuel wood and the resulting accelerated destruction of forests in parts of Africa, Asia, and Latin America are seen as a profound ecological challenge. Eckholm comments that the destruction of forests is expected to result in the undermining of the land's productivity because of increased soil erosion, severe flooding, creeping deserts and declining soil fertility. Lack of firewood in India, Pakistan and Bangladesh has forced the poor to burn cow dung. This is robbing the country's farm land of an estimted one-third of its chemical fertilizers. Firewood is contributing to a food problem and this recently prompted an Indian official to say "Even if we somehow grow enough food for all of our people in the year 2000, how in the world will they cook it?"

How does this all relate to Project 3250? To me it means that the handwriting is on the wall. North America is beginning to experience the "people problem." We, as an industry, can expect more and more competition for what once we considered our fiber supply. We are not going to be able to obtain major amounts of fiber from developing countries. Programs like Project 3250, which has the objective of increasing per acre fiber production and improving fiber quality, should be expanded rather than supported reluctantly and at a level that results in a curtailment of activity.

ASPEN GENETICS AND TREE IMPROVEMENT PROGRAM

1975 CROSSING PROGRAM

The major emphasis from this point on in the Project 3250 program will be on producing large numbers of seed and seedlings from proven parent material. These parents have been evaluated for a number of years in terms of form, wood quality, disease resistance, ease of crossing and the quality of progeny produced. This year, a number of crosses between proven parents had in excess of 200 catkins pollinated and two dry site crosses each had approximately 800 catkins pollinated.

Twenty-five crosses were made at the Institute and eight crosses were made by foreign cooperators using pollen from IPC selected male parents. We also used pollen from European _P. tremula_ on several _P. tremuloides_ females and shared the resulting seed with the foreign cooperators in both instances. This kind of cooperative arrangement allows us to make use of selected European _Populus_ materials. Three hundred _P. davidiana_ seedlings were also received from Dr. Louis Zsuffa in Canada. Table I summarizes crosses made and parent trees used. Table II gives seed production figures and related information. Table III provides data on seedling production.

A number of parent trees, particularly _P. alba_ and _P. grandidentata_, did not perform well this year and it is fortunate we had seed stored from previous years. In good seed years, we attempt to store as much seed as possible by freezing it over calcium chloride. This seed is then used in years of poor flowering and/or seed production.

TABLE I

SUMMARY OF 1975 CROSSES AND LOCATION OF PARENT TREES

Cross No.[a]	Parents (female x male)		
XT-1-75	Clone 2 (Wausau, WI)	x	T-46-60 (Ralph, MI)
XCa-T-2-75	Ca-2 (Czechoslovakia)	x	T-16-60 (Bruce Crossing, MI)
XCa-T-3-75	Ca-2 (Czechoslovakia)	x	T-10-60 (Ontonagon, MI)
XT-4-75	T-5-61 (Ontonagon, MI)	x	T-44-60 (Ralph, MI)
XCa-T-5-75	Ca-2 (Czechoslovakia)	x	T-44-60 (Ralph, MI)
XT-6-75	T-1-58 (Ontonagon, MI)	x	T-44-60 (Ralph, MI)
XT-Ca-7-75	T-5-61 (Ontonagon, MI)	x	Ca-1-62 (Czechoslovakia)
XT-Ta-8-75	T-5-61 (Ontonagon, MI)	x	Ta-2-75 (East Prussia)
XT-Ta-9-75	T-5-61 (Ontonagon, MI)	x	Ta-1-75 (East Prussia)
XT-Ca-10-75	T-1-58 (Ontonagon, MI)	x	Ca-1-62 (Czechoslovakia)
XT-Ta-11-75	T-1-58 (Ontonagon, MI)	x	Ta-2-75 (East Prussia)
XT-Ta-12-75	T-1-58 (Ontonagon, MI)	x	Ta-1-75 (East Prussia)
XG-Ca-13-75	G-9-63 (Bruce, WI)	x	Ca-1-62 (Czechoslovakia)
XCa-G-14-75	Ca-2 (Czechoslovakia)	x	G-2-58 (Ontonagon, MI)
XCa-G-15-75	Ca-2 (Czechoslovakia)	x	G-1-65 (Breed, WI)
XTa-T-16-75	Ta-3-75 (East Prussia)	x	T-44-60 (Ralph, MI)

TABLE I (Continued)

SUMMARY OF 1975 CROSSES AND LOCATION OF PARENT TREES

Cross No.[a]	Parents (female x male)		
XG-Ca-17-75	G-10-62 (Bonita, WI)	x	Ca-1-62 (Czechoslovakia)
XCa-G-18-75	Ca-2 (Czechoslovakia)	x	G-11-62 (Bonita, WI)
XA-G-19-75	A-1, No. 15 (Czechoslovakia)	x	G-1-65 (Breed, WI)
XA-G-20-75	A-1, No. 16 (Czechoslovakia)	x	G-11-62 (Bonita, WI)
XA-G-21-75	A-1, No. 16 (Czechoslovakia)	x	G-1-75 (Rural, WI)
XCa-G-22-75	Ca-2 (Czechoslovakia)	x	G-1-75 (Rural, WI)
XA-Gla-23-75	A-1, No. 15 (Czechoslovakia)	x	Gla-1-75 (Korea)
XT-Gla-24-75	T-53-60 (Fern, WI)	x	Gla-1-75 (Korea)
XT-25-75	T-53-60 (Fern, WI)	x	XT-217-72, No. 22 (4n) (Appleton, WI)
XCa-G-26-75	Ca-2 (Czechoslovakia)	x	G-2-75 (Appleton, WI)
XTa-T-27-75	Ta-4-75 (Germany)	z	T-46-60 (Ralph, MI)
XT-Ta-28-75	Ta-4-75 (Germany)	x	T-5-75 (Ontario)
XTa-T-29-75	Ta-5-75 (Germany)	x	T-44-60 (Ralph, MI)
XTa-T-30-75	Ta-5-75 (Germany)	x	T-46-60 (Ralph, MI)
XTa-T-31-75	Ta-5-75 (Germany)	x	T-5-75 (Ontario)
XTa-T-32-75	Ta-5-75 (Germany)	x	T-6-75 (Ontario)
XT-33-75	T-7-75 (Ontario)	x	T-46-60 (Ralph, MI)

TABLE I (Continued)

SUMMARY OF 1975 CROSSES AND LOCATION OF PARENT TREES

Cross No.[a]	Parents (female x male)		
XDa-34-75	Seed received from S. Hyun, Korea		
XT-0-35-75	T-1-75 (Appleton, WI)	x	Open-pollinated
XT-0-36-75	T-1-58 (Ontonagon, MI)	x	Open-pollinated
XT-0-37-75	T-80-57 (Alston, MI)	x	Open-pollinated
XT-0-38-75	T-130-56 (Bruce Crossing, MI)	x	Open-pollinated
XT-0-39-75	Clone 2 (Wausau, WI)	x	Open-pollinated
XT-0-40-75	T-2-75 (Breed, WI)	x	Open-pollinated
XT-0-41-75	T-3-75 (Breed, WI)	x	Open-pollinated
XT-0-42-75	T-4-75 (Breed, WI)	x	Open-pollinated
XG-0-43-75	G-3-75 (Breed, WI)	x	Open-pollinated
XG-0-44-75	G-4-75 (Breed, WI)	x	Open-pollinated
XG-0-45-75	G-5-75 (Breed, WI)	x	Open-pollinated
XA-Gla-46-75	Seed received from Jung Suk Choi, Korea		

[a]X = cross, A = P. alba, Ca = P. canescens, Da = P. davidiana, G = P. grandidentata, Gla = P. glandulosa, O = open pollinated, T = P. tremuloides, Ta = P. tremula.

TABLE II

SUMMARY OF 1975 SEED PRODUCTION

Cross[a]	No. Catkins Poll.	Amount Seeds	Seeds/ Catkin[b]	Germ., %
XT-1-75	185	52,630	259	91
XCa-T-2-75	335	50,343	146	97
XCa-T-3-75	355	51,564	141	97
XT-4-75	246	54,834	183	82
XCa-T-5-75	383	47,984	123	98
XT-6-75	200	37,968	182	96
XT-Ca-7-75	208	32,058	126	82
XT-Ta-8-75	120	36,963	305	99
XT-Ta-9-75	120	7,026	57	97
XT-Ca-10-75	110	1,106	10	99
XT-Ta-11-75	83	658	--	--[c]
XT-Ta-12-75	64	220	--	--[c]
XG-Ca-13-75	300	--	--	--
XCa-G-14-75	184	42,618	93	40
XCa-G-15-75	834	72,320	65	75
XTa-T-16-75	--[d]	4,460	--	53
XG-Ca-17-75	330	1,920	2	40
XCa-G-18-75	215	17,617	52	63
XA-G-19-75	250	1,564	>1	1
XA-G-20-75	145	772	--	--[c]
XA-G-21-75	200	828	--	--[c]
XCa-G-22-75	899	34,985	31	80
XA-Gla-23-75	120	0	--	--
XT-Gla-24-75	63	0	--	--
XT-25-75	6	514	44	51
XCa-G-26-75	47	751	--	--[c]
XTa-T-27-75	--[d]	400	--	40
XTa-T-28-75	--[d]	1,000	--	60
XTa-T-29-75	--[d]	500	--	90
XTa-T-30-75	--[d]	250	--	70
XTa-T-31-75	--[d]	1,000	--	70
XTa-T-32-75	--[d]	1,000	--	90
XT-33-75	--[d]	1,000	--	45

[a] X = cross, A = P. alba, Ca = P. canescens, G = P. grandidentata, Gla = P. glandulosa, T = P. tremuloides, Ta = P. tremula.
[b] Amount of seed, seeds per catkin pollinated and germination percent based upon 40-mesh and larger seed for all crosses except numbers 13 through 15 and number 17.
[c] Seed numbers too small to run germination percent.
[d] Crosses made in Germany and number of catkins pollinated is unknown.

TABLE III

SUMMARY OF 1975 SEEDLING PRODUCTION

Cross No.[a]	Total No. Plantable Seedlings Produced	No. Undersized Seedlings Produced[b]
XT-11-73	64	40
XCa-T-5-75	2075	1500
XT-Ca-7-75	1126	1000
XT-Ta-8-75	2412	3900
XT-Ta-9-75	485	750
XT-Ca-10-75	75	100
XT-Ta-11-75	244	500
XT-Ta-12-75	66	50
XCa-G-15-75	2440	2700
XTa-T-16-75	303	300
XG-Ca-17-75	36	30
XCa-G-18-75	354	300
XA-G-21-75	49	17
XCa-G-22-75	1184	3700
XCa-G-26-75	114	75
XTa-T-27-75	30	0
XTa-T-28-75	4	0
XTa-T-29-75	3	0
XTa-T-30-75	0	20
XTa-T-31-75	60	40
XTa-T-32-75	110	150
XT-0-36-75	2490	300
XT-0-37-75	504	0
T Mix	471	0
XCa-T Mix	927	500
XT-Da-Mix	4354	3400

[a] X = cross, A = *P. alba*, Ca = *P. canescens*, Da = *P. davidiana*, G = *P. grandidentata*, 0 = open pollinated, T = *P. tremuloides*, Ta = *P. tremula*.
[b] Approximate numbers only.

The techniques used in both crossing aspen and producing seedlings have been comprehensively described and reports are available upon request. They are entitled "Procedures for Crossing Bigtooth and Quaking Aspen" and "Procedures for Growing Aspen and Aspen Hybrids from Seed."

Quaking Aspen Crosses

Several straight quaking aspen crosses ("tremuloides x tremuloides") were made and the seed was used with 1974 stored quaking aspen seed to insure producing enough seedlings for orders received through the Ruffed Grouse Society of North America. Many of these seedlings were grown by the Nekoosa Edwards Nursery, with whom we have worked out a cooperative arrangement for the production of large numbers of seedlings.

The Swedish tetraploid P. tremula, Ta-10, and the grafts we have of the tree did not flower this past year and we were, therefore, unable to make any triploid hybrid crosses. We have heard, however, that the Swedish tree is flowering this year and pollen will be available for crosses in 1976. We did make a number of diploid P. tremuloides x P. tremula and P. tremula x P. tremuloides crosses with European cooperators although the numbers of seeds and seedlings obtained from this arrangement were not large. We hope to repeat some of these crosses again in 1976.

Bigtooth Aspen Crosses

An attempt was made again this year to produce large numbers of dry site seedlings. The P. canescens female, Ca-2, was used with a number of bigtooth males, resulting in the production of about 168,000 seeds. Unfortunately, only one of the bigtooth males performed satisfactorily this past year out of five bigtooth males used. This reduced the amount of seed obtained and, in some instances, necessitated repeating crosses.

No "straight" bigtooth crosses were made again this year as past performance has been unsatisfactory.

Other Types of Crosses

No cottonwood crosses were made in 1975. Crosses from earlier crossing programs are now in various outplantings, and a reasonable period of evaluation of their performance is necessary before further action in cottonwood crossing will be taken.

We did obtain *P. glandulosa* pollen from Korea and applied it to a *P. alba* and a *P. tremuloides* female. Hybrids of this type have been reported to grow well in both upland and heavy soils. However, the pollen was not viable and no seed was produced.

Seedling Production

The IPC seedbeds were sown the last week in May. One-half of the seedbeds were covered with plastic and the rest were covered with muslin. The possible advantages of using muslin were covered in Project 3250, Progress Report One. They include: (1) The ability to maintain optimum moisture in the seedbeds, as the muslin will allow passage of moisture from overhead sprinklers, but will disperse the water droplets so as to minimize any washing effect on the seeds, caused either by overhead sprinklers, or heavy rainfall. (2) The muslin provides shading for the young seedlings, helping to lower seedbed temperatures, especially important when the seeding date is somewhat later than normal. The evaporation of moisture retained in the muslin itself will also help lower seedbed temperatures. (3) The muslin also will allow a moderate air exchange in and out of the seedbed.

A comparison was made between the two types of covers this year. For comparable square footage of seedbeds, 1818 seedlings with an average height of

1.4 feet were produced under plastic and 1389 seedlings with an average height of 1.4 feet were produced under muslin. Approximately 300 more plantable seedlings were produced under plastic. However, it is hard to assess how meaningful these differences (15-20% more plantable seedlings produced under plastic) are since different crosses were involved with each type of cover. Muslin is easier to work with since it does not have to be rolled up for watering like the plastic. The total cost of the muslin operation is also less than plastic and the muslin can be reused. Consequently, more of our beds will be covered with muslin in the future.

Average seedling size was less this year than in previous years. It is difficult to determine why they were smaller although it probably can be attributed to lack of experience on the part of present nursery personnel. It appeared that some of the seedbeds were overwatered. Also, the muslin was probably left on too long, resulting in excessive shading. It is fortunate that we had a sizeable amount of lineout material to supplement seedling numbers. Figure 1 illustrates the appearance of the 1975 seedbeds.

Nekoosa Edwards agreed to grow aspen seedlings in their nursery this past year and they produced 23,500 quaking aspen seedlings and 8650 P. canescens hybrids. The quaking aspen seedlings will be used to fill orders received from members of the Ruffed Grouse Society of North America and the P. canescens hybrids will be supplied to cooperating agencies.

TRIPLOID ASPEN PRODUCTION USING TETRAPLOID POLLEN

Triploid quaking aspen (Populus tremuloides Michx.) has been found to be superior to normal diploid quaking aspen in terms of growth, fiber characteristics and pulping properties. Triploids can be produced by crossing diploid quaking aspen with tetraploid aspen. Large numbers of triploid trees have been produced at The Institute of Paper Chemistry by crossing native diploid quaking aspen with a Swedish P. tremula tetraploid. However, flowering of the Swedish tree has been sporadic and it has the additional disadvantage of growing at a more northern latitude than Lake States aspen. It is possible that progeny from a cross with the Swedish tetraploid as one of the parents may not fully utilize the longer growing season available in the Lake States.

Figure 1. View of the 1975 Seedbeds

The production of additional tetraploids for mass triploid production has been the aim of a 20-year program at the Institute. A number of techniques have been tried to induce tetraploids, including the use of colchicine (1) as well as triploid x triploid and triploid x tetraploid crosses. However, the most promising technique has been the fertilization of haploid (1n) egg cells in flowers of diploid aspen with unreduced (3n) pollen from triploid aspen as reported by Winton and Einspahr (2). Briefly, this technique (2) involves dry screening pollen of triploid aspen to concentrate the occasional, large, unreduced pollen grains. Early work in the use of unreduced pollen to produce tetraploids was carried out by Müntzing (3) and Nilsson-Ehle (4). Theoretically, each of the largest pollen grains should contain three complete sets of chromosomes (3). The screened fraction is then applied to diploid aspen flowers. This procedure has the advantage that, because fertilization is involved, all cells should have tetraploid counts. Three putative tetraploids have been recovered to date using this technique. All have had chromosome counts consistently in the tetraploid range (66 to 78)*.

One of the tetraploid prospects (XT-217-72, No. 22) was originally produced through a cross between a selection from a diploid quaking aspen cross and a naturally occurring triploid quaking aspen as the male parent. In this particular cross (XT-217-72), 26 catkins were pollinated with the screened pollen and 23 catkins recovered. Seed produced included 22 seeds which were retained on a 40-mesh screen and 4 seeds which were retained on a 50-mesh screen. The putative tetraploid, No. 22, was recovered from the 40-mesh seed. Illustrated in Fig. 2 is a leaf cell with a $4n$ count from XT-217-72, No. 22.

The 1972 tetraploid was used in a cross in the spring of 1975, having flowered unusually early (three years of age). The pollen from this putative tetraploid was applied to a diploid female quaking aspen. Confirmation that tree No. 22 was a normally functioning tetraploid would be obtained if most of the progeny produced had triploid counts. Forty-two seedlings were produced from this cross. Several collections were made of leaf material from all the seedlings, stained using the technique of Winton (5) and counted. Thirty-nine seedlings had triploid counts, two had diploid or mostly diploid counts and one seedling

*Chromosome numbers are as follows: diploid = 38, triploid = 57 and tetraploid = 76.

was unable to be counted due to the poor condition of the cells when examined after being squashed. Illustrated in Fig. 3 is a cell from one of the triploid seedlings of this cross (left) and a cell from one of the two diploids (right). Obtaining triploid counts on a majority of seedlings (93%) confirms the identity of XT-217-22, No. 22, as a tetraploid and the usefulness of the unreduced pollen grain technique to produce tetraploids.

Figure 2. Leaf Cell from the 1972 Tetraploid Quaking Aspen, XT-217-72, No. 22

GROWING HYBRID ASPEN IN NORTHERN WISCONSIN — AN ECONOMIC ANALYSIS

Introduction

There are many ways that can be used to examine the economic potential of growing hybrid aspen. The approach used in this study was to look at "the present worth of future returns" for a series of short rotations. Variations of this approach have been widely used to evaluate silvicultural treatments and to determine optimum rotation ages (6-9). The technique is known as Faustman criterion of maximizing soil rent or land expectation values (10). The approach used is to determine the silviculture and management costs associated with the management scheme selected, carry these costs forward at a predetermined interest rate to the end of the rotation, subtract these "capitalized" costs from the harvest returns and discount the net returns (or loss) back to time zero. This procedure gives the present worth of future returns for a single rotation. By repeating this step for a series of rotations, returns from a long-term management scheme can be determined.

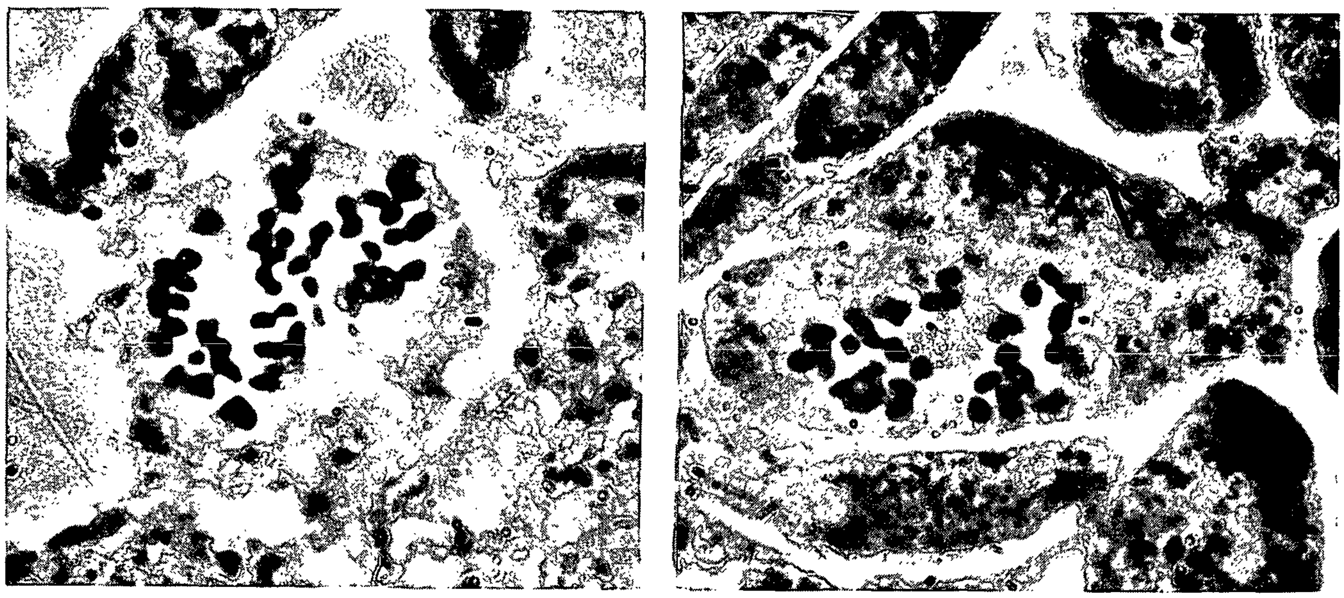


Figure 3. Leaf Cells of Progeny from a Cross Between a Diploid Quaking Aspen Female and the Tetraploid Quaking Aspen, XT-217-72, No. 22. On the Left is a Cell with 57 Chromosomes (Triploid) and on the Right is a Cell with 38 Chromosomes (Diploid)

Forest Management Assumptions

The assumptions made in the study were that the organization involved was a pulp and paper company that was interested primarily in the production of fiber on medium-quality hardwood sites (Vilas fine sand or the equivalent) in northern Wisconsin. Further, it was assumed the company had completed harvesting (clearcutting) the existing stand and was faced with a decision regarding future use of the site. Examined in the study are the economic returns from: (1) growing hybrid aspen, (2) growing red pine, or (3) allowing natural northern hardwood regeneration to again take over the site. The major emphasis in the study involves the potential of growing aspen hybrids.

Further assumptions were that the harvesting operation had prepared the site for planting either red pine or hybrid aspen, future harvesting would be via "full-tree chipping[1]," and the area was to be committed to the production of fiber for the next 90 years. Establishment costs include the cost of planting stock, planting, and in the case of red pine, the release (freeing from vegetative competition) of the trees during the second growing season.

The study investigates a number of possible management options for hybrid aspen and compares the expected returns with returns from: (1) planting and growing red pine (a limited number of options) and (2) letting the area regenerate naturally into northern hardwoods. Because of the difficulty of estimating future interest rates, stumpage prices and establishment costs, a number of combinations of the factors listed were examined[2]. Table IV lists the variables investigated for hybrid aspen. No attempt was made to optimize the returns from growing red pine but several near optimum fiber production schemes, as noted in Table V, were examined. The analyses involving northern hardwoods assumed that there would be no regeneration cost and that the annual forest management cost (taxes and management charges) would be the same as for aspen and red pine ($2/acre/year).

The growth rates used in determining the optimum rotation age for aspen and for comparing the growth of aspen with red pine and northern hardwoods are summarized in Table VI. The hybrid aspen growth was obtained from growth curves constructed from measurement data obtained from two triploid hybrid aspen crosses

[1]Use of the entire aerial part of the tree, excluding needles and leaves.
[2]Stumpage price is the return to the land owner for growing the trees and is the price paid for standing trees. Establishment costs include cost of planting and planting stock.

growing at the St. Regis Ripco Experimental Farm. The red pine growth information was obtained from information on (1) growth and yield of red pine in Minnesota (11) and (2) growth of Wisconsin coniferous plantations in relation to soils (12). The actual values used were from (1) and were adjusted upward by 20% to take into account the yield gains expected as a result of full-tree chipping. Northern hardwood growth rates are average values based upon growth of upland hardwoods from sources (13-15) with the figures used representing volume growth that has been adjusted upward (50-100%) to account for anticipated increased yield from "full tree" chipping. The 75 cu.ft./acre/year value is considered to be the growth rate for an average site and the 100 cu.ft./acre/year for a good northern hardwood site in northern Wisconsin.

TABLE IV

ECONOMIC VARIABLES INVESTIGATED — HYBRID ASPEN

Variables	Values Investigated
Interest rates, %	4, 6, 8 and 10
Rotation ages, years	8, 10, 13, 15, 18, and 20
Stumpage prices, ¢/cu.ft.	5, 10, 15, 20 and Variables I[a] and II[b]
Establishment costs, $/acre	75, 100, 125
Growth rate, cu.ft./acre/year	From growth curve, see Table III

[a]Variable I = stumpage price of $0.039/cu.ft. ($3.50/cord) and increasing at 1.0%/year starting at year one.

[b]Variable II = stumpage price of $0.056/cu.ft. ($5.00/cord) at year one and increasing at 1 1/2% annually.

TABLE V

ECONOMIC VARIABLES INVESTIGATED — RED PINE AND NORTHERN HARDWOOD

Variables	Values Investigated
— Red Pine —	
Interest rates, %	4, 6, 8, 10
Rotation ages, years	30, 45
Stumpage prices, ¢/cu.ft.	5, 10, 15, 20 and variable[a]
Establishment costs, $/acre	50, 75, 100
Growth rate, cu.ft./acre/year[b]	Age 30 — 106 Age 45 — 144
— Northern Hardwoods —	
Interest rates, %	4, 6, 8, 10
Rotation age, years	45
Stumpage price, ¢/cu.ft.	5, 10, 15, 20 and variable[a]
Establishment costs, $/acre	0
Growth rate, cu.ft./acre/year[c]	75, 100

[a] Stumpage price increasing at 1%/year and 1 1/2%/year.
[b] Age 30 and Age 45 rotation age figures based upon mean annual growth figures from (11) and from site index 60, BA 150 ft^2 tables. Values have been adjusted upward by 20% to account for increased yield from whole tree chipping.
[c] Average values based upon growth of upland hardwoods from several authors (13-15) with the figure used representing growth that has been adjusted upward (50 to 100%) to account for increased yield from whole tree chipping.

TABLE VI

GROWTH RATES AND TOTAL PRODUCTION — 90 YEARS[a]

Species	Rotation Years	First Rotation, cu.ft./acre	Subsequent Rotations, cu.ft./acre	Total Production 90 Year Period, cu.ft./acre
Hybrid Aspen[b]	8	495	790	9,270
	10	980	1,665	14,300
	13	1,994	2,990	19,935
	15	2,859	4,000	22,860
	18	4,014	5,220	24,895
	20	4,845	5,815	23,995
Red Pine	30	3,180	3,180	9,540
	45	6,480	6,480	12,960
Northern Hardwoods[c]	45	3,375	3,375	6,750
	45	4,500	4,500	9,000

[a] Total production is the number of cubic feet of pulp wood produced in 90 years for a series of short rotations of the length specified.
[b] Growth of hybrid aspen based upon plantation measurements. See Fig. 23, Appendix.
[c] Growth rates used were 75 and 100 cu.ft./acre/year and represent medium and high growth rates for the site involved.

Stumpage prices, along with interest rates, have a considerable influence on the economic returns that will result from growing trees. Stumpage prices vary considerably depending upon accessibility, harvesting difficulty, etc. Three-year averages for the Wisconsin Department of Natural Resources (1972, 1973, and 1974) vary greatly as shown in Table VII for sales on state lands. Prices for good quality accessible aspen stumpage reached a new high during the past three-year period with a number of sales at greater than $10.00 per cord. Stumpage price discussions in "The Timber Outlook of the United States" (16) suggests that 75% of the total future pulpwood price increases will go to stumpage and 25% to harvesting and transportation costs. Scarcity of available wood supply is the reason cited for the 75/25% split. Everything points to higher future stumpage prices but there is little basis for determining how much higher prices will go. Several authors (9, 16-17) have suggested projected pulpwood prices will increase from 0.5 to 1.5% (compounded) per year. Based upon existing price information and the knowledge that future prices will be greater, two approaches were used. One involved using several constant prices, each modestly greater than existing pulpwood prices and the second approach was to use a variable (increasing) future price. The variable price was based upon the premise that existing average stumpage prices will increase at a rate of 1% or 1 1/2% per year. Appendix Table XLIII summarizes the stumpage prices used.

TABLE VII

STUMPAGE PRICES — STATE OF WISCONSIN
AVERAGE ALL SALES (1972, 73, 74) ON PUBLIC LAND[a]

Species	Units Sold	Unit Value, dollars			Product and Units
		Low	High	Average	
Red pine	48,418	1.00	22.00	7.63	Cordwood, cords
Mixed northern hardwoods	185,211	0.50	20.00	1.91	Cordwood, cords
Aspen	943,709	0.68	13.60	3.50	Cordwood, cords

[a]Provided by T. J. Rausch and compiled by the Wisconsin Department of Natural Resources. Data includes all sales on state, county, and federal lands.

Aspen Hybrids — Economic Analysis

Optimum rotation age and the rate of return on investment for present-day economic conditions are two items of considerable interest. Table IV summarizes the variables used in investigating the optimum rotation age and the expected rate of return from growing hybrid aspen. Not shown in Table IV is the growth rate information. Growth rates used are summarized in Table VI.

The values used were obtained by plotting actual plantation and sucker stand data over age and fitting a least squares curve through the data. The curve used is given in the Appendix, (Fig. 23). Values for growth beyond age fifteen are extrapolated values and represent our best estimate for growth at the ages shown. Evidence to date indicates the growth of sucker stands produced by cutting the original plantation, will exceed the growth of the original plantation. The magnitude of the growth differences is shown in Table VI. The economic analysis assumed one growth rate for the first rotation and an increased growth rate (as shown) and no establishment costs for all subsequent rotations. Table VI also gives a summary of the total expected volume production over the 90-year comparison period for the several rotation lengths (8, 10, 13, 15, 18 and 20) investigated.

Optimum Rotation Age

The optimum rotation was determined by running all combinations of the variables listed in Table IV. The optimum rotations for the site conditions at the St. Regis (now Wausau Mills) test area were determined as being the rotation that gives the maximum land expectation values (present worth of future returns). The results of this series of computer runs clearly demonstrated (see Appendix Tables XLIV-XLVII) that the optimum rotation age was 18 years when the required interest rate was 4 or 6% and 15 years when the required return on investment was 8 or 10%. Interest rate was the variable that has had the most influence on the optimum rotation age.

Table VIII illustrates the land expectation values (present value of future returns) when plantation establishment costs were assumed to be $100/acre and stumpage price was either $9.00/cord or $5.00/cord and increasing at an annual rate of 1.5% per year. The optimum length of rotation, as indicated by the underlined values, is either 15 or 18 years depending upon the required rate of return on investment. One way the land expectation values given in Table VIII can be interpreted is that the values given are what a company could pay for an acre of land if their economic situation required they receive either 4, 6, 8 or 10% interest on their investment. For Table VIII, where $100/acre establishment costs were assumed, stumpage prices are $0.10 per cubic foot ($9.00/cord) and, given a required rate of return of 6%, a company could pay $104.61 for an acre of land if they managed hybrid aspen on an 18-year rotation.

TABLE VIII

LAND EXPECTATION VALUES — HYBRID ASPEN[a]

Rotation Length, years	Interest Rate, %[b] 4	6	8	10	Total Wood Production, cu.ft./acre[c]
	— $0.10 Stumpage Price[a] —				
10	141.73	38.02	-13.18	-41.95	14,300
13	234.68	86.14	14.02	-25.82	19,935
15	272.88	104.14	23.02	-21.44	22,860
18	285.88	104.61	18.91	-27.23	24,895
20	279.09	98.45	12.88	-32.90	23,995
	— Variable Stumpage Price[a] —				
13	216.71	54.88	-13.74	-47.94	19,935
15	258.71	72.89	-4.99	-43.51	22,860
18	280.24	77.96	-5.47	-46.08	24,895
20	273.83	74.34	-8.91	-49.42	23,995

[a] Land expectation value after 90 years of forest management (present worth of future returns). Calculations based upon $100/acre establishment costs, an annual management charge of $2/acre/year, a constant stumpage price of $0.10/cu.ft. for the first illustration and a starting stumpage price of $0.056/cu.ft. compounded yearly at a rate of 1.5% for the second illustration.
[b] Anticipated interest rate or return on investment.
[c] Total wood produced over the 90-year management period.

Rate of Return on Investment

Another use that can be made of the values in Table VIII is in determining the rate of return on investment when the cost of an acre of land is known. The procedure used is to plot, for a specified rotation age, the land expectation values over the rate of interest (see Fig. 4). Illustrated are the curves for rotation ages 10 and 15 years when the stumpage price is $0.10/cubic feet. Using the curve for a 15-year rotation and by assigning the required land value costs of $50, $75 and/or $100/acre, the rate of return on investment would be either 7.3%, 6.6%, or 6.1%, depending upon the amount of investment required for the land.

Table IX summarizes the rate of return information for the several options given in Table VIII. Based upon what appears to be a fairly reasonable set of assumptions, the rate of return for growing hybrid aspen is expected to be between 5.5 and 7.0% when either 15 or 18-year rotations are employed. Not included in the rate of return is the return that will occur over the 90-year period because of increasing land values. This was not included because such returns would occur regardless of what type of forest management option (aspen, pine, or hardwoods) was selected.

Red Pine and Northern Hardwoods — Economic Analysis

One logical alternative to growing hybrid aspen is to plant red pine on the area and a second alternative is to allow the area to regenerate naturally and grow two 45-year rotations of northern hardwoods. These two alternatives were investigated and the results of this investigation are described in detail in the Appendix under (1) Red Pine — Economic Analysis and (2) Northern Hardwoods — Economic Analysis.

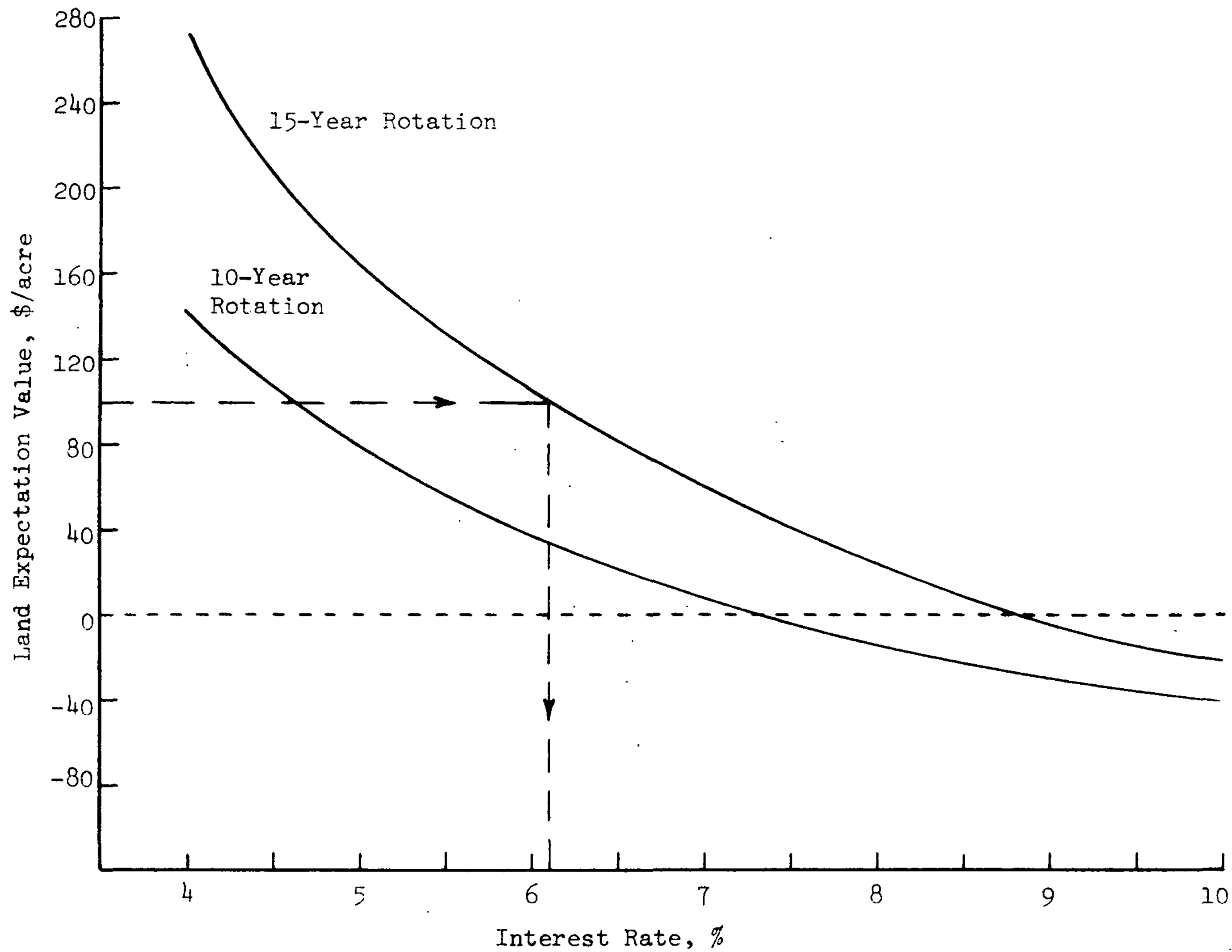


Figure 4. Rate of Return on Investment is Determined by Plotting Land Expectation Values Over Interest Rate for A Specific Rotation. Then, Using an Assigned Land Value, the Rate of Return can be Read from the Curve as Shown by the Example ($100/Acre gives 6.1% Rate of Return)

TABLE IX

HYBRID ASPEN RATE OF RETURN IN INVESTMENT, PERCENT[a]

Rotation Length, years	Land Values, $/acre 50	75	100
	— $0.10/cu.ft. Stumpage Price —		
10	5.7	5.1	4.6
13	6.9	6.3	5.7
15	7.3	6.6	6.1
18	7.2	6.6	6.1
20	7.0	6.5	6.0
	— Variable ($0.05/cu.ft. and 1-1/2%) Stumpage —		
13	6.1	5.6	5.3
15	6.4	6.0	5.6
18	6.5	6.0	5.7
20	6.4	6.0	5.6

[a]Calculations based upon $100.00/acre establishment cost and other variables as indicated.

Briefly, it appears the rate of return for growing red pine for fiber is expected to range from 3.4 to 5.4%. To obtain a rate of return of approximately 5% requires the plantation establishment cost to be no more than $75/acre, stumpage prices to be in excess of $13.50/cord and land prices to be about $50/acre. Reduction of establishment cost greatly improves the rate of return on investment because of the relatively long rotation ages being used. The total cubic-foot volume production over the 90-year period is expected to be about 9,540 cubic feet for the 30-year rotation and 12,960 cubic feet when managed on a 45-year rotation. These total production figures are approximately one-half of the expected production from hybrid aspen.

Northern hardwoods stumpage prices are low and growth rates less than for hybrid aspen or red pine. When the rate of return was determined for northern hardwoods, even without establishment costs and greater-than-average stumpage prices, rates of return were less than 1%.

Summary of Results

Growth comparisons and stumpage price information clearly demonstrated that the optimum rotation age for hybrid aspen is 15 years when the required interest rate was 8 or 10% and 18 years when the interest rates were 4 or 6%. The economic analysis procedure assumed that the production of fiber was required and that the forest manager was faced with a decision of whether to grow hybrid aspen, grow red pine or do little or nothing in the way of forest management and grow northern hardwoods. Table X compares these three alternatives using land expectation values, total wood production and return on investment. Interest rates, stumpage values, and annual management costs influence the land expectation values shown. Opinions vary on what interest rates, stumpage prices and management costs should be used in such comparisons and the values used (see Table X, footnotes) are our present best estimates for the species involved.

Based upon the information presented in Table X, hybrid aspen has the highest land expectation values, will produce the greatest amount of wood and will give a return on investment of about 6% when land costs are assigned at a value of $75/acre. Red pine, despite relatively low total volume production, will provide about a 5% return on investment because of the anticipated high (perhaps too high) stumpage values involved. The rate of return for northern hardwoods when land values are $75/acre is expected to be less than 1% and is low because of slow growth and low stumpage values.

TABLE X

BETWEEN SPECIES COMPARISON OF LAND EXPECTATION VALUES, TOTAL WOOD PRODUCTION AND RETURN ON INVESTMENT

Species	Rotation Length, years	Interest Rate, %[a] 6	8	10	Total Wood Production (90 yr), cu.ft.	Rate Return, $75.00 Land Invest., %
Hybrid aspen[b]	15	72.89	-4.99	-43.51	22,860	5.9
	18	77.96	-5.47	-46.08	24,895	6.0
Red pine[c]	30	5.83	-43.50	-64.84	9,540	4.9
	45	3.01	-55.59	-76.22	12,960	5.1
Northern hardwoods[d]	45	+3.85	-4.30	-6.53	9,000	<1

[a] Land expectation values ($/acre) after 90 years of forest management.
[b] Hybrid aspen calculations based upon: $100/acre establishment costs, $2/acre annual management costs and stumpage prices of $5/cord increasing at 1-1/2% annually.
[c] Red pine calculations based upon $75/acre establishment costs, $2/acre annual management costs and a $10/cord stumpage price that increases 1-1/2% annually.
[d] Northern hardwood calculations based upon 100 cu.ft/acre/year growth, no establishment costs, $1/acre annual management costs and stumpage prices of $2.50/cord increasing at 1-1/2% annually.

The procedures used in the economic evaluation of hybrid aspen did not consider costs and growth response associated with such intensive forest management practices as fertilization and irrigation. Data is being accumulated which will make the economic evaluation of such procedures possible during the coming year. The computer program developed for the economic analysis described in this report has the flexibility of handling these additional factors. The results of these further economic evaluations will appear in the next progress report.

ESTABLISHMENT AND PERFORMANCE OF MATERIALS IN FIELD TRIALS

Three *P. canescens* x *P. grandidentata* seed orchards were planted this past year, one at the Millston Test Area and two on cooperator lands. A *P. tremuloides* x *P. tremula* triploid seed orchard is expected to be put in this coming spring if enough stock can be produced in the greenhouse during the winter months. There has been some difficulty in propagating the tetraploid male used in producing triploid seedlings; consequently, the triploid seed orchards will not be planted as soon as originally intended. However, the "canescens x bigtooth" seed orchards are on schedule and for the most part doing well.

Twenty-three field trials were measured in 1975; sixteen were aspen and seven were cottonwood. The remainder of the trials were under observations throughout the summer and fall. A leaf disease has appeared on certain "alba x bigtooth" hybrids and has been under close observation. Further discussion of the disease can be found in the Millston Test Area Section.

The growing conditions during 1975 were quite good, with adequate rainfall and near normal temperatures. The month of August was above average in rainfall for most of the state with the central portion receiving four inches above normal. The good growing season was reflected by the growth of most trials, particularly those on the normally dry sites.

Clintonville Test Area — (IPC)

The Clintonville Test Area is located near the Wolf River, south of Shawano, Wisconsin. The area is a dry, sandy site and was intended to serve as a test for various crosses under conditions of prolonged dryness. Earlier trials at Clintonville tested *P. grandidentata* x *P. grandidentata* crosses. The establishment of "straight bigtooth" materials has proven to be very difficult. As a consequence, these earlier trials had low survival and almost negligible growth. Table XI lists the two regularly measured trials remaining. Most of the area is now intended to serve as a breeding arboretum to complement the one at the Greenville Test Area. A sand point was put down this past summer and a small portable pump is being used to place water on the arboretum trees when periods of reduced rainfall occur. It is felt that the climatic differences between the Clintonville and the Greenville areas will assure a supply of flower buds from one or both areas.

Two trials at Clintonville were measured this year: Larch Trial III and Trial XIV. A brief growth summary for the 15 years they have been established is given in Tables XII and XIII.

The P. alba x P. grandidentata cross XA-G-22-59 in Trial XIV has begun to show signs of a leaf disease that has also occurred on other "alba x bigtooth" hybrids. Although not serious, the disease warrants observation and efforts are being made to determine its identity (see Millston Test Area Discussion).

TABLE XI

CLINTONVILLE TEST AREA

Number	Trial Title	Date Established	Year Last Measured	Report Last Described[a]
XIV	Test good hybrids on a sandy site	1961	1975	24
Larch III	Test adaptability of certain exotic species of larch	1961	1975	22

[a]Project 1800 reports. Spare copies of Project 1800 reports are not available. However, upon request additional details can be provided for experimental trials of interest.

TABLE XII

LARCH TRIAL III
15-YEAR MEASUREMENTS

Material		Av. Ht., ft	Av. DBH, in.	Survival, %
LS-1-59	(*Larix sibirica*)	8.2	0.9	31
LL-2-59	(*Larix leptolepis*)	23.6	3.3	77
LL-4-59	(*Larix leptolepis*)	27.9	4.7	75
LD-9-59	(European x Japanese larch)	26.6	4.4	67
LL-12-59	(*Larix leptolepis*)	29.3	4.6	84
LG-13-59	(*Larix gmelini*)	22.1	3.2	56
LD-14-59	(*Larix dahurica* var. *koreana*)	26.9	4.1	86
LG-15-59	(*Larix gmelini*)	17.1	2.6	29

TABLE XIII

TRIAL XIV
15-YEAR MEASUREMENTS

Material[a]	Av. Ht., ft	Av. DBH, in.	Survival, %
XA-G-22-59	47.3	6.9	67
T-160	30.7	3.8	55
XT-Da-18-59	50.1	6.9	75

[a]See Appendix for code used in describing test materials.

Cunard Test Area — (Kimberly-Clark Corporation)

The Cunard area is located 22 miles east of Iron Mountain, Michigan. From the beginning, the area has been difficult to maintain. A high water table and poor drainage made cultivation on a regular basis very difficult. Erratic maintenance produced heavy vegetative competition from which three trials never fully recovered, despite release efforts.

One trial (LI) is showing promise. It is comprised primarily of *tremuloides* x *tremula* triploid crosses which have shown an ability to do better on heavy textured, more poorly drained soils than other types of material. This is the only trial on the area that will remain on a regular measurement schedule. Table XIV lists the trials now under observation or on a regular measurement schedule at the Cunard Area.

TABLE XIV

CUNARD TEST AREA

Number	Trial Title	Date Established	Year Last Measured	Report Last Described[a]
XLIII	1968 test of *P. canescens* hybrids	1968	1972	24
XLV	Comparison of 1969 *P. tremuloides* and *P. tremula* combinations	1969	1973	25
LI	Comparison of 1970 triploid progeny from interspecific crosses of *P. tremuloides* and *P. tremula*	1970	1974	24

[a]Project 1800 reports. Spare copies of Project 1800 reports are not available. However, upon request additional details can be provided for experimental trials of interest.

Greenville Test Area — (IPC)

The Greenville Test Areas I and II are located ten miles northwest of Appleton, Wisconsin. The first area contains an aspen breeding arboretum, several aspen and cottonwood trials, and the nursery. The second area has a cottonwood breeding arboretum and several cottonwood trials. Table XV lists the trials on the Greenville areas.

TABLE XV

GREENVILLE TEST AREA

Number	Trial Title	Date Estab-lished	Year Last Measured	Report Last Described[a]
VII	Crosses to study the heritability of selected properties	1958 1959 1960	1972 1973 1974	24 25 12
VIII	F_2 progenies for selection and studies on inheritance	1958	1972	24
IX	Seedlings from pollen irradiated to induce mutation	1958	1972	25
XXI	Comparison of cottonwood seedlings from 1968 modified diallel crosses	1964	1973	21
XXVIII	Comparison of three poplar selections	1965	1974	21
XXIX	Comparison and evaluation of three 1964 cottonwood crosses	1965	1974	21
XXXIV	Evaluation of several promising black poplar clones and selected seedlings of controlled cotton-wood crosses	1966	1975	22
XXXV	Clonal testing of selected seed-lings from the 1962-1967 cotton-wood crosses	1963 1964 1965 1966 1967 1968	1975 1968 1968 1970 1971 1972	24 18 18 18 18 24
XL	1967 Comparison of cottonwood crosses	1967	1971	21
XLIV	1968 Comparison of cottonwood crosses	1968	1972	24
XLVI	Comparison of 1968 crosses	1969	1973	25
XLVII	1969 Hybrid poplar clonal test	1969	1973	25
XLVIII	Clonal testing of selected seedlings	1969 1971	1975 1975	25 23
LII	Comparison of cottonwood seedlings from 1969 modified diallel crosses	1970	1974	24
LIII	Clonal test and arboretum planting of elite selections from University of Wisconsin poplar program	1970	1974	24
LIV	Comparison of 1970 cottonwood crosses and hybrids	1971	1975	25
LV	Comparison of 1970 cottonwood crosses and hybrids	1971	1975	25
LVI	Comparison of 1971 cottonwood crosses and hybrids	1972	1974	24
LXIII	Progeny test of several 1972 and 1973 crosses	1974	1975	--
LXIV	Clonal test of selected individuals from 1963 crosses	1974	1975	--

[a]Project 1800 reports. Spare copies of Project 1800 reports are not available. However, upon request additional details can be provided for experimental trials of interest.

Seven trials were measured at the Greenville areas this fall. One particular trial, XXXIV, produced excellent growth over a ten-year period. The trial tests cottonwood materials of both clonal and seedling origin. One of the better materials in the trial, D-9-65, is illustrated in Fig. 5. The individual shown has a dbh of 9.1 inches and a total height of 44.5 feet at the end of ten years. The tree had an added growth advantage in that it was a corner tree with crown exposure on three sides which also contributed to the heavy branching that may be noted. Table XVI gives the heights and diameters of the materials at ages five and ten. Survival is not included; the trial was thinned at age five. Height and diameter growth was good for most materials, with heights frequently averaging over four feet per year and diameters averaging over 0.5 inch per year.

Figure 5. A 10-Year-Old Individual from Material D-9-65 Growing in Trial XXXIV at Greenville, Wisconsin. Tree is 44.5 Feet in Height and 9.1 Inches dbh

TABLE XVI

TRIAL XXXIV
HEIGHT AND DIAMETER GROWTH OF COTTONWOOD AND COTTONWOOD HYBRIDS

Material[a]	5th-Year Av. Total Height, ft	5th-Year Av. dbh, inch	10th-Year Av. Total Height, ft	10th-Year Av. dbh, inch
TS-1-61	13.5	1.3	32.4	3.8
DH-4-62	24.5	2.9	45.6	6.0
DH-8-62	23.4	3.1	41.8	6.4
DH-9-62	29.0	3.8	47.9	7.0
D-9-65	26.2	2.9	45.9	6.0
D-12-65	25.2	2.9	48.6	6.5
D-13-65	24.2	2.8	45.7	5.7
DH-15-65	20.1	2.6	32.2	4.4
XD-37-65	22.1	2.6	41.5	5.6
XD-38-65	20.4	2.4	41.8	5.6
XD-41-65	18.3	2.2	38.0	5.4
XD-42-65	20.0	2.4	39.1	5.6
XD-43-65	17.1	1.8	28.9	3.5
XD-44-65	11.7	0.8	23.7	2.7

[a]See Appendix II for code used in describing test materials.

<u>Millston Test Area</u> — (Wisconsin Department of Natural Resources)

The Millston area is located 13 miles east of Black River Falls, Wisconsin. It is a dry site, having a sand texture with a low water table and infrequent summer rains.

The earlier trials planted at Millston were intended primarily to evaluate *P. grandidentata* x *P. grandidentata* crosses. Again, as at the Clintonville site, growth and survival were minimal, supporting the growing concern that "straight bigtooth" crosses required more effort to establish than their hybrids. Later trials shifted emphasis to bigtooth hybrids which demonstrated a much greater potential than the "straight bigtooth" as a material capable of occupying sandier, drier sites. Table XVII lists the trials on the Millston Test Area.

A _P._ _canescens_ x _P._ _grandidentata_ arboretum was planted at Millston this past spring similar to those now on Packaging Corporation lands near Manistee, Michigan, and on Blandin Paper Company lands near Grand Rapids, Minnesota. A sand point was put down at Millston allowing the placement of water on the arboretum trees when men were working at the test area and when periods of no rain occurred. Figure 6 illustrates clean cultivation of the Millston arboretum during the first year of establishment. An area adjoining the "canescens x bigtooth" arboretum was plowed and disked prior to next spring's planting of a triploid arboretum using diploid _P._ _tremuloides_ females and a tetraploid _P._ _tremula_ male.

A leaf disease has appeared during the past three years on several hybrids with "alba x bigtooth" parentage. It occurs late in the growing season and to this point has not been serious. The disease is typified by a color change of the leaves with earliest symptoms appearing as yellow and orange progressing to a deep chocolate-brown in the latest stages. Eventual defoliation occurs, starting in the lower crown and spreading upward, although a small number of infected leaves are persistent and may hold until late fall or early winter.

Correspondence with Dr. Louis Zsuffa of the Ontario Forest Research Branch has indicated that similar symptoms have been noted on "alba x bigtooth" hybrids in Canada and Massachusetts. The causal fungus was identified as _Plagiostoma_ _populi_. The organism attacking the hybrids at Millston has not been conclusively identified but all indications point toward the same fungus identified

TABLE XVII

MILLSTON TEST AREA

Number	Trial Title	Date Established	Year Last Measured	Report Last Described[a]
XXXI	Test and compare bigtooth hybrids on a dry site	1966	1975	18
XXXVI	Compare and evaluate aspen crosses	1967	1971	21
XXXVII	Test depth of planting for effect on survival and growth	1967	1971	21
XLI	1968 Comparison of selected "*alba* x bigtooth" clones	1968	1973	25
XLII	1968 Test of *P. canescens* hybrids produced for dry, sandy sites	1968	1973	25
LVII	Evaluation of growth and variability in "*tremuloides* x *canescens*" and "*tremuloides* x *davidiana*" hybrids on dry, sandy soils	1973	1975	25
LVIII	Evaluation of growth and variability of "*canescens* x bigtooth" and "*alba* x bigtooth" aspen hybrids on dry, sandy soils	1973	1975	25
LIX	Consolidate best trees of 1962 and 1964 bigtooth aspen crosses (G) with seedlings from five 1972 G crosses	1973	1975	25
LX	Simple, nonreplicated block planting of several promising bigtooth aspen hybrids to demonstrate the growth and variability of such hybrids on sandy, dry sites	1973	1975	25

[a]Project 1800 reports. Spare copies of Project 1800 reports are not available. However, upon request additional details can be provided for experimental trials of interest.

by Dr. Zsuffa. The effect of the defoliation is felt to be minimal because of the lateness in the growing season at which it occurs. However, there has been an occasional tip dieback associated with the disease that needs to be closely watched. Resistance to the disease has been observed in varying degrees between clones and certain clones have shown almost complete resistance. More will be reported as information becomes available.

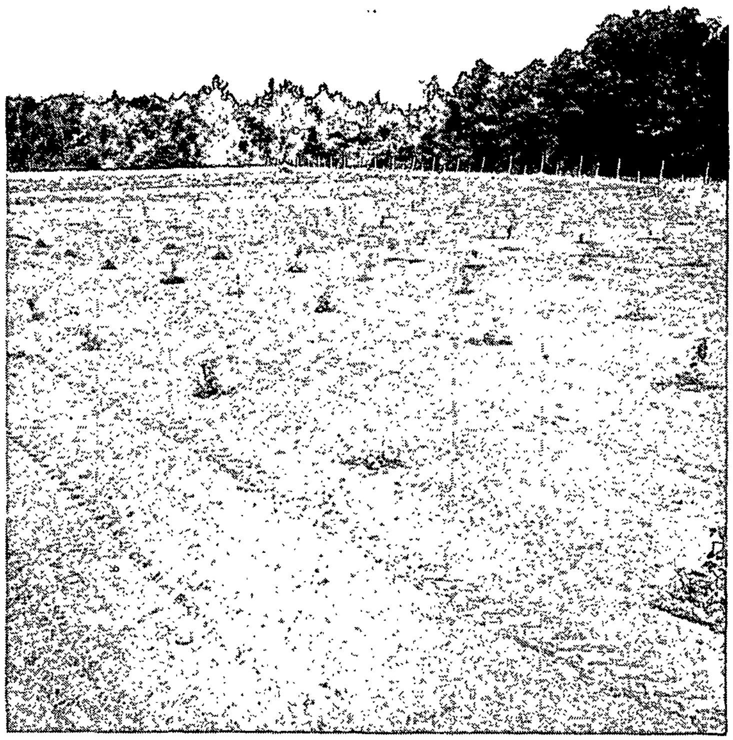


Figure 6. Illustrated is the "canescens x bigtooth" Arboretum at the Millston Test Area 2 Months After Planting Demonstrating Clean Cultivation. The Area in the Upper Left is the Site for the "<u>tremuloides</u> x <u>tremula</u>" Triploid Arboretum

Figure 7 illustrates two materials in Trial LVIII, a trial designed to evaluate bigtooth hybrids on dry sandy soils. The hybrid on the left is a cross between a bigtooth female and a canescens male. The form and growth within this type of cross appears to be quite variable; however, there are individuals with excellent form and growth that have been selected for clonal propagation on a large scale. The hybrid on the right is a cross between an alba female and a bigtooth male. This type of cross has produced the best growth and survival in the trial. Typically, "alba x bigtooth" hybrids do well on dry sites but tend to have numerous heavy branches. It is felt that after harvesting, the tight spacing produced by the resultant sucker stand will eliminate much of the early heavy branching.

Ripco Test Area — (Wausau Paper Mills Co.)

The Ripco Test Area is located south of Eagle River, Wisconsin on the Ripco Experimental Forest. The area is divided into three compartments, each with a soil texture classified as Vilas fine sandy loam.

Project Report One stated that a P. tremuloides x P. tremula triploid hybrid arboretum was to be established on the Ripco Test Area. A decision has since been made to place the arboretum at the Millston Test Area near the existing "canescens x bigtooth" arboretum, thus facilitating the maintenance of both arboretums by using the existing sand point and being able to cultivate both at the same time.

The post-emergence herbicide* used at Ripco prior to spring and fall planting has shown itself to be effective. However, control of the major target

*"Roundup" — developed by the Monsanto Company, Agricultural Division. Available for experimental purposes only.

Figure 7. Material on the Left is a 3-Year-Old "alba x bigtooth" Hybrid from Cross XA-G-44-72. Tree is 13.8 Feet in Height and 0.9 Inch dbh. This Year's Growth was 6.3 Feet. Material on the Right is a "bigtooth x canescens" Hybrid from Cross XG-Ca-37-72 Showing Very Good Form and Moderate Growth of 11 Feet in Height and 0.9 Inch dbh. Both Individuals are Growing in Trial LVIII at the Millston Test Area

species (quack grass) was not good beyond the first year after treatment. Densities the second year after treatment were still less than untreated areas but sufficient to create competition. No adverse effects to planting stock have been noted when planting occurred five days after treatment and at intervals up to nine months after treatment. Both spring and fall applications of the herbicide appear to give comparable control. The duration of control could be increased by timing the treatment to coincide with the most active growth period for the target species and, in the case of quack grass, increasing the level of herbicide from 2 lb/acre to 3-4 lb/acre.

No trials were measured at Ripco this fall but observations indicate that growth has been good for most materials. Trial area maintenance will be continued and, if sufficient planting stock is available, a second triploid hybrid arboretum will be established. Table XVIII lists the trials on the Ripco Area.

TABLE XVIII

RIPCO TEST AREA

Number	Trial Title	Date Established	Year Last Measured	Report Last Described[a]
X	Comparison of natural and artifically produced trip-loids with diploid control trees	1959	1973	25
X		1959	1973	25
XI	Comparison of performance of selected materials on contrasting sites	1959	1973	25
XVI	Comparison of interspecific and intraspecific hybrids produced in 1960-1961	1962	1971	16
XVII	Evaluation of the most promising 1961 aspen crosses	1962	1971	16
XXIV	Comparison and evaluation of 1964 quaking aspen crosses	1965	1974	21
XXV	Clonal comparison of selected triploid and diploid trees	1965	1974	25
Larch I	Preliminary larch adaptability study	1958	1972	18
LXII	Test the effectiveness of the herbicide "roundup" prior to spring and fall planting	1974	1974	--

[a]Project 1800 reports. Spare copies of Project 1800 reports are not available. However, upon request additional details can be provided for experimental trials of interest.

INTENSIVE MANAGEMENT OF ASPEN AND ASPEN HYBRIDS

ESTABLISHMENT AND GROWTH OF ASPEN HYBRIDS UNDER OPTIMUM GROWING CONDITIONS

Silvicultural Trial II

ST-II is located near Monico, Wisconsin on the Consolidated Papers, Inc. nursery. It was planted in May, 1969 and received fertilizer applications in the spring of 1970 and 1973. The objective of the trial was to maximize growth on two "alba x bigtooth" hybrids using treatments of irrigation, fertilization, irrigation and fertilization, and control. A diagram of the trial can be found in Fig. 8.

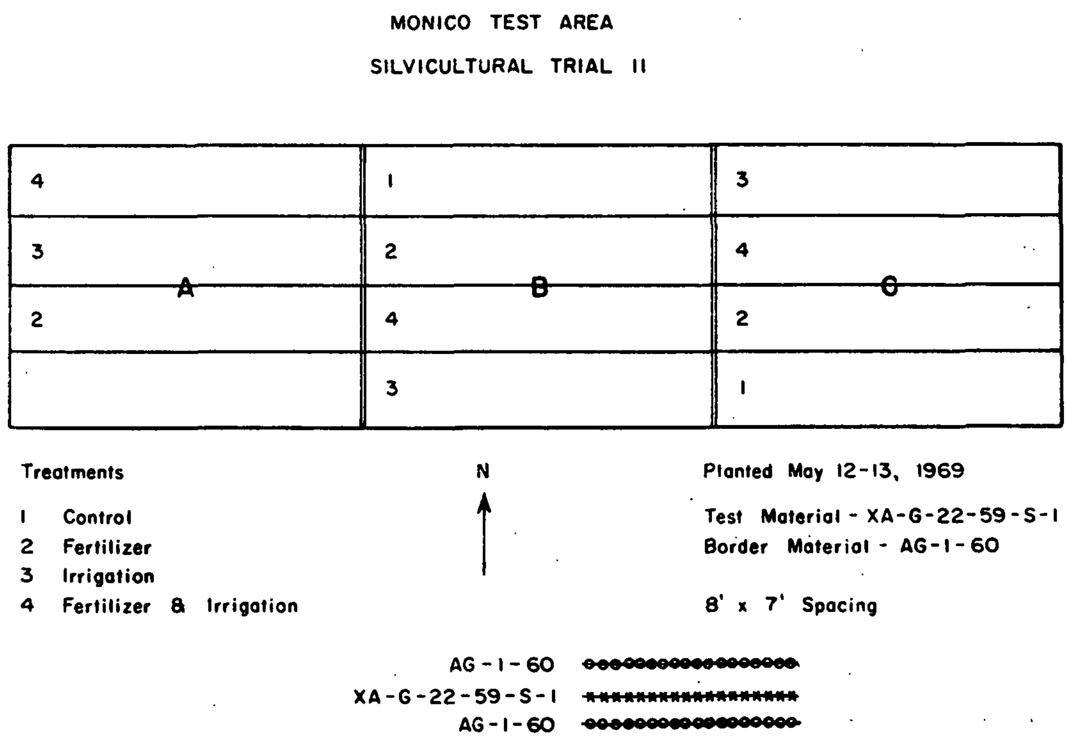


Figure 8. Treatment and Replication Arrangements of Silvicultural Trial II Located at the Consolidated Papers, Inc. Nursery Near Monico, Wisconsin

1975 marked the end of regular measurements of ST-II. The trial has been placed on an observation basis but volume information will be obtained when the plots reach age 10. Growth during the past year was good with the border trees exhibiting height growth of from 2-5 feet. The test trees have been supressed by the border trees and are unable to maintain the same rate of growth. It is because of this edge effect and the concern that root extensions between plots had occurred that the decision to discontinue measurements was made.

Final leaf samples were collected the last week of August from all plots in ST-II. Collections in previous years included both test and border trees, but were limited to only border trees in 1975. The objectives of the collections and subsequent analyses were to evaluate the effectiveness of the fertilizer treatments and to add further to our knowledge of optimum and minimum levels of essential nutrients in the leaves of Populus sp. Table XIX summarizes the levels of N, P, K, Ca, and Mg found in the leaves. The values presented are the average of three replications.

Nitrogen and potassium appear to be depressing magnesium uptake on the fertilizer plots. This is shown by the significant difference in magnesium levels of the leaves between the fertilized and nonfertilized plots. Similar results were obtained in earlier studies at the Monico Nursery and have also been reported by other researchers.

The nitrogen differences noted in Table XIX are not significant. However, it does appear that there is continued nitrogen uptake on the fertilized plots this year, indicating that there may still be a nutrient carryover response.

Table XX is a six-year comparison of nutrient levels of the leaves on fertilized plots versus nonfertilized plots, disregarding irrigation. Fertilization occurred in the spring of 1970 and 1973. Influence of the fertilization, particularly nitrogen, declined through the third growing season and response beyond this is negligible. Reapplication of fertilizer produced an increase during 1973 in nutrient uptake of nitrogen and potassium. During 1974 and 1975 the same general nutrient level decline occurred following fertilization as was noted during the previous three-year period.

TABLE XIX

SILVICULTURAL TRIAL II
LEVEL OF NUTRIENTS IN THE LEAVES OF BORDER TREES[a]

(Percentage dry weight)

Treatment	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Control	2.49	0.21	0.83	1.27	0.36[x]
Fertilizer	2.78	0.22	0.79	1.40	0.24[y]
Irrigation	2.45	0.24	0.76	1.40	0.37[x]
Fertilizer + irrigation	2.61	0.22	0.92	1.31	0.29[y]
"F" Test[b] for treatments:	NS	NS	NS	NS	S

[a]The border trees were AG-1-60. Values presented are the average of three replications and are expressed as % dry weight.

[b]Analysis of variance "F" test for treatments. "S" indicates values significant at the 5% level of probability. "NS" — nonsignificant test.

[xy]Duncan's Multiple Range Test (18) was calculated when "F" test values for treatments were significant. Values followed by a common superscript letter are not significantly different.

TABLE XX

SILVICULTURAL TRIAL II
SUMMARY 1970-1975 NUTRIENT LEVEL LEAVES

Element and Treatment	Dry Weight, %					
	1970[a]	1971	1972	1973[a]	1974	1975
Nitrogen						
Fertilized	3.52	2.64	2.79	3.83	3.00	2.70
Nonfertilized	2.67	2.38	2.78	3.15	2.81	2.47
Phosphorus						
Fertilized	0.20	0.19	0.22	0.26	0.22	0.22
Nonfertilized	0.22	0.20	0.22	0.25	0.21	0.23
Potassium						
Fertilized	0.86	0.95	0.86	1.17	1.08	0.86
Nonfertilized	0.78	0.90	0.82	0.96	1.02	0.80
Calcium						
Fertilized	1.15	1.09	0.92	0.93	0.91	1.36
Nonfertilized	1.16	1.13	1.01	1.12	1.02	1.34
Magnesium						
Fertilized	0.33	0.24	0.28	0.32	0.21	0.27
Nonfertilized	0.39	0.32	0.32	0.40	0.32	0.37

[a] Fertilizer treatments reapplied spring 1973.

Silvicultural Trial III

Silvicultural Trial III is also located at the Consolidated Papers, Inc. Nursery near Monico, Wisconsin and was planted in the spring of 1970. The objective of this trial is to demonstrate the biological potential of triploid hybrid aspen. The statistical design and treatments to be used are very similar to those used in Silvicultural Trial II. The trial is a three-replicate, randomized block, split-plot design and the treatments used included irrigation, fertilization, irrigation plus fertilization, and a control with no treatment.

Soils of the Area

Soil samples taken of the surface horizon and "B" horizon indicated the texture of the surface soil was a loamy sand that graded rapidly into sand at 8 to 10 inches. The subsoil samples exhibited lower levels of essential nutrients than the surface soils. Also demonstrated quite clearly is an east-to-west variation in soil nutrient levels with Replication C having lower levels of N, P, K, Ca, and Mg. The overall nutrient levels for the entire trial appeared to be adequate for moderate rates of growth. The soils of the trial were again sampled in the fall of 1973 and there was little evidence of "carryover" from fertilizer applied in the spring of 1971.

Methods and Materials

The statistical design employed is a three-replicate, randomized block, split-plot design in which each plot consists of three rows of 18 trees each. The center row contains the test materials which are being measured and sampled extensively. The border rows have been planted with a second type of triploid material and superimposed on the planting are the fertilizer and irrigation treatments. Figure 9 illustrates the location of the treatments.

Two sources of triploid hybrid aspen were planted for use as test and border trees. A triploid hybrid (XT-Ta-14-58, S-1) was selected to be the test material. This tree was one of the best trees in a five-year-old trial growing on Vilas fine sandy loam soil near Eagle River, Wisconsin. The border trees are seedlings from Experimental Cross XT-Ta-10-69, which is a triploid hybrid cross identical in parentage to Cross XT-Ta-14-58. Using the clone for the test trees provides some reduction in the variability of the test material. Using the seedlings for border trees will result in a demonstration of the growth potential of a triploid hybrid cross.

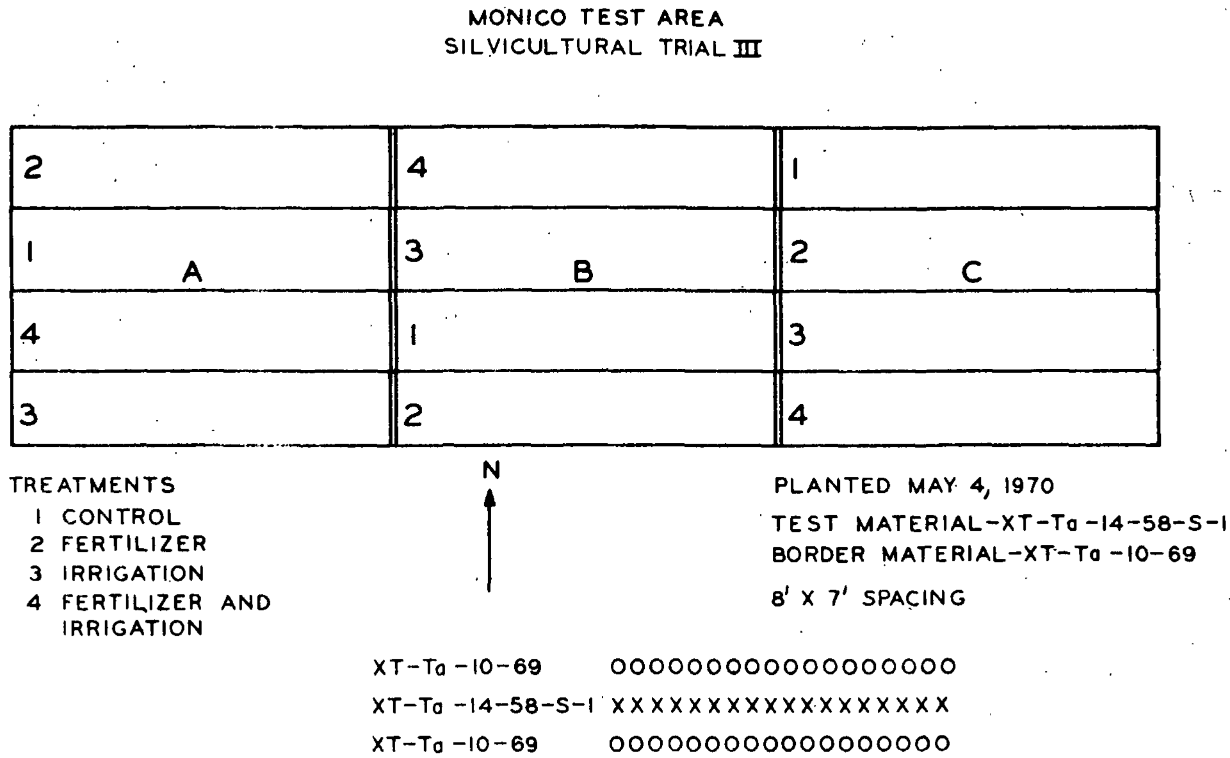


Figure 9. Treatment and Replication Arrangements of Silvicultural Trial III Located at the Consolidated Papers, Inc. Nursery Near Monico, Wisconsin

The fertilizer treatment, which consisted of 1000 lb/acre of $N_{20}P_5K_{10}Ca_{20}Mg_4$, was applied on July 1 of the second growing season (1971) and was cultivated into the soil. The trial was fertilized again in the spring of 1974 using the same levels as used in 1971 with the exception that the potassium level was increased to 20%. Irrigation treatments were applied via overhead sprinklers prior to 1974, and through a below-the-crown irrigation system in 1974 and 1975. The aim was to maintain the soil moisture between field capacity and 60% of field capacity. Records on temperature, rainfall, and the time and amount of supplemental water applied during the 1975 growing season were maintained. Temperatures were normal or slightly above normal (July), rainfall was a little below normal and a total of 4.2 inches of water (2.2 inches applied in July) was required to keep the moisture levels near field capacity.

First Five Years' Growth

The planting stock used in this trial was variable in size and, although survival and first-year growth were satisfactory, there was considerable variability between replications that were scheduled to receive the same treatment. Table XXI summarizes the 1970 through 1974 height growth data. Because of planting stock variability, all measurements and evaluations have been based upon the best fifteen test trees in each replication. Height growth differences due to the treatments during the first four years after treatment, although greatest for the fertilizer plus irrigation treatment, were not statistically significant. Statistically significant differences in diameter and total volume growth were obtained for the third and fourth growing seasons.

TABLE XXI

FIRST FIVE YEARS GROWTH OF SILVICULTURAL TRIAL III[a]
(XT-Ta-14-58, S-1)

Treatment	Average Total Height, ft				
	1970	1971	1972	1973	1974
Control	3.8	7.6	10.2	14.1	17.6
Fertilizer	4.0	7.2	10.1	14.7	18.2
Irrigation	4.1	7.6	10.4	15.4	18.5
Fertilizer + irrigation	4.3	7.4	11.0	16.5	19.9

[a]Height and growth information based upon three replications of each treatment and upon the best 15 of 18 test trees in each replication.

Fifth-year growth (1974) of the test trees on control plots averaged 3.5 feet in height and 0.46 inch in diameter growth while growth on the best treatment (fertilizer plus irrigation) averaged 3.4 feet in height and 0.62 inch in diameter growth. Neither height nor diameter growth differences were statistically significant and the lack of response appeared to be due primarily to the low amount of irrigation water (0.96 inch) applied in 1974.

Sixth-Year Growth

The border and test trees have responded in a similar manner to the treatments. Growth of the border trees, however, has been greater than that of the test trees. Height, diameter, and volume growth information taken after the sixth growing season (1975) for both test and border trees are summarized in Table XXII. Included are the results of the analyses of variance and Duncan's Multiple Range Test calculations. Figure 10 illustrates the form and growth of the border trees in Silvicultural Trial III.

Height growth (1975) was greater and diameter growth was approximately equal to that of 1974 for both the test and border trees. Average total height, although greater for the fertilizer and irrigation treatments, still was not significantly different from the control. The trees receiving a combination of fertilizer plus irrigation were significantly taller than trees on the control plots. Average diameter and average total volume (Table XXII) were significantly influenced by the treatments with the trees apparently responding to both improved soil fertility and improved soil moisture. Greatest response appears to be due to fertilization. Growth during the sixth growing season was also evaluated. Neither height growth alone nor diameter growth alone were statistically significant and sixth-year volume growth (which combined diameter and height) was significantly increased with the fertilizer giving greater response than irrigation.

Volume growth values (Table XXII), because of the method of calculation, are believed to be higher than they should be. Using the growth information from both the test and border trees and making the assumption of 70 square feet growing space per tree (622 trees/acre) and 90% survival, a more realistic estimate of early growth of the triploid hybrids is obtained. Table XXIII summarized the results of such calculations. A standard analysis of variance and Duncan's Multiple

TABLE XXII

SILVICULTURAL TRIAL III
HEIGHT, DIAMETER AND VOLUME GROWTH
1975 MEASUREMENTS

Treatments[a]	Av. Total Ht., ft	Av. Diam., BH, in.[b]	Av. Total Vol. per Acre, cu ft[c]	6th-Year Growth Ht., ft	6th-Year Growth Diam., inch	6th-Year Growth Vol., cu ft/acre
Test Trees (XT-Ta-14-58, S-1)						
Control	21.2^{x}	2.20^{x}	209.1^{x}	3.6	0.43	97.1^{x}
Fertilizer	22.5^{xy}	2.63^{yz}	297.1^{xy}	4.3	0.60	147.5^{xyz}
Irrigation	23.6^{xy}	2.42^{xy}	274.3^{x}	5.1	0.45	131.2^{xy}
Fertilizer + irrigation	25.4^{y}	2.84^{z}	392.3^{y}	5.5	0.57	195.2^{z}
"F" Test[d] for treatments:	S	S	S	NS	NS	S
Border Trees (XT-Ta-10-69)						
Control	22.2^{x}	2.45^{x}	279.9^{x}	4.8	0.52	136.3^{x}
Fertilizer	23.7^{xy}	2.96^{zy}	417.4^{yz}	5.2	0.69	221.6^{xyz}
Irrigation	23.6^{xy}	2.76^{xy}	374.8^{xy}	5.3	0.59	191.7^{xy}
Fertilizer + irrigation	25.8^{y}	3.26^{z}	534.9^{z}	5.9	0.73	281.4^{z}
"F" Test[d] for treatments:	S	S	S	NS	NS	S

[a] Values given are an average of three replications and are based upon the best 15 of 18 trees in each replication and the best 30 of 36 trees in each replication of the border trees.

[b] Average diameter breast height in inches.

[c] Volume growth estimated on the basis of 100% survival of 778 trees per acre. Bella's (19) formula used to estimate tree dry weight and volume.

[d] Analysis of variance "F" test for treatments. "S" indicates values significant at the 5% level of probability. "NS" — nonsignificant test.

[xyz] Duncan's Multiple Range Test; means followed by a common superscript are not significantly different.

Range Test were used to compare treatments. A fairly reliable estimate of early response to fertilization and irrigation can be obtained by assigning the control plots a value of 100. When this is done, the relative volume growth response due to fertilization was 159.8%, irrigation 139.2%, and fertilization plus irrigation 205.1% (increases of 60, 39, and 105%). Growth response appears to be due to improvement in both soil moisture and soil fertility levels. Response to fertilizer appears, at this point in time, to be greater than that due to irrigation. Interestingly, growth on the irrigation plus fertilization treated plots was approximately 2 cords/acre/year during the sixth growing season.

Figure 10. Growth and Form of Triploid Hybrid Aspen Border Trees (XT-Ta-10-69) Growing on One of the "Fertilizer + Irrigation" Plots of ST-III. Age 6 Years, Average Height 24.7 Feet and 3.1 Inches Diameter bh

TABLE XXIII

SILVICULTURAL TRIAL III
HEIGHT, DIAMETER AND VOLUME DATA FOR COMBINED TEST AND BORDER TREES GROWTH AFTER SIX YEARS

Treatment[a]	Av. Total Ht., ft	Av. Diam., BH, in.[b]	Av. Total Vol. per Acre, cu ft[c]	6th-Year Growth Ht., ft	6th-Year Growth Diam., inch	6th-Year Growth Vol., cu ft/acre
Control	21.9^{x}	2.37^{x}	184.5^{x}	4.4	0.49	88.7^{x}
Fertilizer	23.3^{x}	2.85^{y}	271.6^{y}	4.9	0.65	141.7^{xy}
Irrigation	23.6^{x}	2.64^{x}	245.7^{xy}	5.2	0.55	123.5^{xy}
Fertilizer + irrigation	25.7^{y}	3.12^{y}	350.9^{z}	5.8	0.69	181.9^{z}
"F" Test[d] for treatments:	S	S	S	NS	NS	S

[a] Values given are an average of three replications and are based upon the best 15 of 18 trees in each replication of the test trees and the best 30 of 36 trees in each replication of the border trees.

[b] Average diameter breast height in inches.

[c] Volume growth estimated on the basis of 90% survival of 622 trees per acre. Bella's (19) formula used to estimate tree dry weight and volume.

[d] Analysis of variance "F" test for treatments. "S" indicates values significant at the 5% level of probability, "NS" — nonsignificant test.

[xy] Duncan's Multiple Range Test; means followed by a common superscript are not significantly different.

Soil Nutrient Status

The soil nutrient status of the area occupied by Silvicultural Trial III was estimated by soil samples taken from the area in 1971 prior to the application of the fertilizer treatments on July 1, 1971. The nutrient status was examined again in the fall of 1973, three growing seasons after the application of fertilizer ($N_{20}P_5K_{10}Ca_{20}Mg_4$) at a rate of 1000 lb/acre. After three years, there were no significant differences in the levels of the major nutrients between the fertilized and nonfertilized plots. As discussed earlier, fertilizer ($N_{20}P_5K_{20}Ca_{20}Mg_4$) at a rate of 1000 lb/acre was reapplied in early June of 1974.

Nutrient Levels in the Leaves

The nutrient levels of the leaves of the test and border trees were sampled at the end of the first growing season (1970), prior to the application of the fertilizer and irrigation treatments. Leaf samples were found to be high in nitrogen and potassium and contained adequate amounts of P, Ca, and Mg. Levels present reflect a combination of nutrient carryover from the nursery and moderate levels in the soil.

Leaves were sampled each fall from 1971 to 1975. Both border and test trees were sampled each fall except in 1975 when only border trees were sampled. There was a significant improvement in nitrogen levels on the fertilized plots over the nonfertilized plots with levels being the highest in 1971. There were no significant differences between treatments for any of the other nutrients. Nitrogen levels in the leaves of both the test trees and the border trees decreased for the fertilized treatments to a point that by the fall of 1973, the differences were no longer significant. Soil fertility measurements taken in 1973 and leaf nutrient levels made it clear that the earlier nursery carryover and the earlier influence of the fertilizer treatments had disappeared. Table XXIV compares the leaf nutrient status when the data from the test and border trees are combined and the fertilized _versus_ nonfertilized information are compared. The greatest change appears to have occurred in levels of nitrogen and to a lesser extent in the level of potassium. After fertilization in the spring of 1974, levels of nitrogen and potassium in the leaves increased to the point that the differences between treatments were statistically significant. Differences between treatments for levels of Ca, Mg, and P were not statistically significant. Leaf samples taken in 1975 (border trees only) were analyzed and Table XXV summarizes the data. As indicated by the "F" test, there were no longer significant differences between treatment in leaf nutrient levels.

TABLE XXIV

SILVICULTURAL TRIAL III
SUMMARY 1970-1975 NUTRIENT LEVEL LEAVES

Element and Treatment	Dry Weight, %					
	1970[a]	1971[b]	1972	1973	1974[b]	1975
Nitrogen						
Fertilized	--	3.58	2.92	2.42	3.10	2.61
Nonfertilized	3.44	2.54	2.44	2.24	2.38	2.60
Phosphorus						
Fertilized	--	0.20	0.19	0.19	0.20	0.19
Nonfertilized	0.26	0.23	0.19	0.20	0.21	0.20
Potassium						
Fertilized	--	0.75	0.80	1.06	1.26	1.00
Nonfertilized	1.20	1.03	0.84	1.04	1.03	0.92
Calcium						
Fertilized	--	1.29	2.37	1.24	1.19	1.82
Nonfertilized	1.20	1.38	2.34	1.23	1.15	1.81
Magnesium						
Fertilized	--	0.20	0.25	0.12	0.19	0.26
Nonfertilized	0.26	0.19	0.24	0.16	0.18	0.30

[a]Control plots only sampled the year before fertilization was applied.

[b]Fertilizer applied July 1, 1971 and June 1974. Leaf samples taken the last week in August.

TABLE XXV

SILVICULTURAL TRIAL III
LEVEL OF NUTRIENTS IN THE LEAVES OF BORDER TREES[a]

Treatment	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Control	2.56	0.21	0.93	1.84	0.33
Fertilizer	2.56	0.19	0.94	1.78	0.23
Irrigation	2.65	0.20	0.92	1.78	0.27
Fertilizer + irrigation	2.66	0.19	1.07	1.87	0.30
"F" Test[b] for treatments:	NS	NS	NS	NS	NS

[a]Border trees only were sampled and the values presented are the average of three replications and are expressed as % dry weight.

[b]Analysis of variance "F" test for treatments. "S" indicates values significant at the 5% level of probability, "NS" — nonsignificant test.

Silvicultural Trial X

Silvicultural Trial X is located at the Consolidated Papers, Inc. Nursery near Monico, Wisconsin. It has as its purpose the demonstration of the growth potential of improved aspen under near optimum nutrient and soil moisture conditions. The soil texture of the site is a loamy sand with numerous small stones. A nutrient analysis of the soil (Progress Report One, Table XXIV) revealed adequate levels of available N, P, and K and exchangeable Ca and Mg. The nutrient status appears to be a little better in Trial X than in nearby Silvicultural Trials II and III.

Methods and Materials

A 4 x 4 latin square design was employed to arrive at differences between materials. There are four replications of four materials with 100 trees per plot. Spacing is nine feet between rows and nine feet within rows. Three of the materials were bare-rooted stock, and one (T-2-56) was in short supply and was established using both bare-rooted stock and actively growing trees growing in plant "plugs."* The planting was done on April 4 and 5, 1973, with the "plugs" being planted on June 14, 1973. The area was irrigated by an overhead sprinkling system to supplement normal raingall during 1973, 1974, and 1975. The trial was fertilized with 300 lb/acre of $N_{20}P_5K_{20}Ca_{20}Mg_4$ in June, 1975. Table XXVI lists the test materials employed and summarizes early height growth.

*"Plugs" — rooted root sprouts growing in elongated bullet-shaped cavities created in a styrofoam block. The roots, in filling the soil cavities, form bullet-shaped "plugs" when removed for planting.

TABLE XXVI

SILVICULTURAL TRIAL X
FIRST THREE YEARS' GROWTH[a]

Material	1973 Av. Ht., ft	1974 Av. Ht., ft	1975 Av. Ht., ft
T-2-56 (3n) Triploid quaking aspen clone	2.0	4.1	7.3
XT-12-58, S-1 (2n) Diploid quaking aspen clone	3.1	5.8	9.6
XT-Ta-14-58, S-3 (3n) Triploid hybrid aspen clone	1.8	4.7	9.4
AG-1-60 (2n) Diploid alba x bigtooth hybrid clone	4.7	7.1	9.9

[a]Average values based upon 4 replications of 36 measured trees per replication.

First Three Years' Growth

Survival for all materials has been good (94-100%) and early growth (1973 and 1974) differences between materials were due to the size of the planting stock. Third-year growth was much improved and, with the exception of AG-1-60, the height growth during 1975 (Table XXVI) more nearly reflects the potential of the materials being tested. Mouse injury to AG-1-60 reduced growth on two of the four replications. Third-year growth for this material should be approximately 4.2 feet instead of 2.8 feet. Analysis of variance "F" tests were run on average height, height growth, and survival and, as Table XXVII illustrates, significant differences were recorded for each of the variables. Figure 11 illustrates the form and vigor of XT-Ta-14-58, S-3.

TABLE XXVII

SILVICULTURAL TRIAL X
SURVIVAL AND HEIGHT GROWTH[a]

Material	1975 Av. Ht., ft	Ht. Growth, ft	Survival, %
T-2-56	7.3[x]	3.2[y]	98[x]
XT-12-58, S-1	9.6[y]	3.8[x]	94[y]
XT-Ta-14-58, S-3	9.4[y]	4.8[x]	95[y]
AG-1-60	9.9[y]	2.8[y]	100[x]
"F" Test for materials[a]	S	S	S

[a]Analysis of variance and Duncan's Multiple Range Test were run on data. The S indicates a significant difference between materials and means followed by a common superscript are not significantly different.

Leaf samples were collected from each of the four types of material in late August of 1975. The results of these collections indicated that, despite the application of 300 lb per acre of fertilizer ($N_{20}P_5K_{20}Ca_{20}Mg_4$), nitrogen and potassium levels in the leaves were below normal and growth response could be expected from fertilization with N and K.

Plans

The trial was fertilized in the spring of 1975 but at a level approximately one-third the intended amount. Plans are to complete the intended fertilization and the fertilizer will be applied at three to four-year intervals thereafter as nutrient levels dictate. Soil moisture levels will be monitored and water will be added to keep the level at 60% of field capacity until the planting reaches age 5. Leaf samples have been taken to determine levels prior to fertilization and future sampling will evaluate the effects of fertilization. Height, diameter and survival will be taken on an annual basis until age 5 and at less frequent intervals from age 5 to age 10.

Figure 11. Triploid Hybrid Selection After Three Years' Growth in ST-X. Average Height for This Material was 9.4 Feet

Silvicultural Trial XI

ST-XI is located on the U.S. Forest Service's Oconto River Seed Orchard in Oconto County, Wisconsin. The planting tests eight materials: six were supplied by The Institute of Paper Chemistry and two by the U.S. Forest Service. Parentage of the material in ST-XI is given in Table XXVIII.

The trial was planted in April of 1974. It tests two spacings, 10 x 10 feet and 10 x 20 feet and is a ten-replicate planting (five at each of two spacings) with 100 trees in each replication.

TABLE XXVIII

PARENTAGE OF TREES USED IN ST-XI

Cross No.[a]	Parentage (female x male)		
XT-9-72	XT-22-56-S-2 (Greenville, WI)	x	T-46-60 (Ralph, MI)
XCa-G-48-72	Ca-2 (Czechoslovakia)	x	G-1-72 (Taylor Co., WI)
XT-Ta-4-73	T-53-60 (Fern, WI)	x	Ta-10 (Sweden)
XT-Ta-6-73	T-1-58 (Ontonagon, MI)	x	Ta-10 (Sweden)
XT-Ta-22-73	T-16-56 (Greenville, WI)	x	Ta-10 (Sweden)
DH-9-62	A cottonwood type hybrid called Raverdeau, originally from France and obtained from Ontario Paper Co., Ltd.		
U.S. Forest Service Material:			
5260	*P. tristis* x *P. balsamifera* (Canada)		
4878	Euro-American Selection (Italy)		

[a]See Appendix for code used in describing test materials.

Growth and survival information is presented in Table XXIX. The clonal selection DH-9-62 (Fig. 12) has produced the best growth and survival of the eight materials tested. This material has shown good form, growth, and survival in several IPC outplantings and similar results are expected in ST-XI. The triploid hybrids are showing only average growth at the end of the second growing season. Moderate early height growth is somewhat typical of the establishment pattern for triploid hybrids. If near normal growing conditions occur next year, the triploids should begin to show vigorous growth.

TABLE XXIX

SILVICULTURAL TRIAL XI
TWO-YEAR GROWTH MEASUREMENTS

	1974		1975	
Material[a]	Av. Ht., ft	Survival, %	Av. Ht., ft	Survival, %
XT-Ta-4-73	1.9	99	4.1	98
XT-Ta-6-73	1.7	99	4.1	97
XT-Ta-22-73	1.5	98	3.4	91
XT-9-72	2.1	98	4.8	96
XCa-G-48-72	2.2	96	5.0	92
DH-9-62	2.6	99	6.4	99
5260[b]	1.0	81	2.7	58
4878[b]	0.9	87	2.4	40

[a]See Appendix for code used in describing test materials.
[b]U.S. Forest Service identification number.

Figure 12. DH-9-62, the Cottonwood Type Hybrid Shown Above, has Outgrown all Other Materials in Trial ST-XI and After Two Years Averages 1.96 Meters (6.4 Feet) in Height

INTENSIVE FORESTRY PRACTICES ON NATURAL SUCKER STANDS

Silvicultural Trial IV

One of the objectives of Project 3250 is to demonstrate the growth potential of natural aspen sucker stands. The specific objective of Silvicultural Trial IV is to investigate the magnitude of growth increases that can be obtained by irrigating and fertilizing a six-year-old aspen sucker stand growing on sandy loam soils near Tomahawk, Wisconsin.

Experimental Area

The test area is an upland sandy site located on the Wisconsin River between Rhinelander and Tomahawk, Wisconsin. The site selected for the trial is a relatively level area approxiately 25 feet above the Wisconsin River. The texture grades from a sandy loam at the 0-6 inch level to a loamy sand at 26-30 inches. The number of stones increases with depth. The surface soils of the area average 59% sand, 33% silt, and 8% clay. Fertility levels are intermediate and soil moisture measurements made on samples of the A and B horizons indicate that the soils of the area have a field capacity of 15-17% and a wilting point of approximately 5-6%. The water table of the experimental area is estimated to drop below 8 feet during the late summer.

Treatments and Experimental Design

Silvicultural Trial IV is located in a six-year-old quaking aspen sucker stand (present age — thirteen years). A three-replicate, completely random design with restrictions was used in locating the treatments (see Fig. 13). Each treated plot is 150 x 200 feet (0.69 acre). Lanes approximately 10-feet wide were brushed out between the plots and a cat;pillar-drawn, deep-running, heavy-duty tree planter was used to cut root connections between the plots. The lanes have been maintained open and the root connections between plots severed by a single pass annually with an Owens-Illinois, Inc. brush disk.

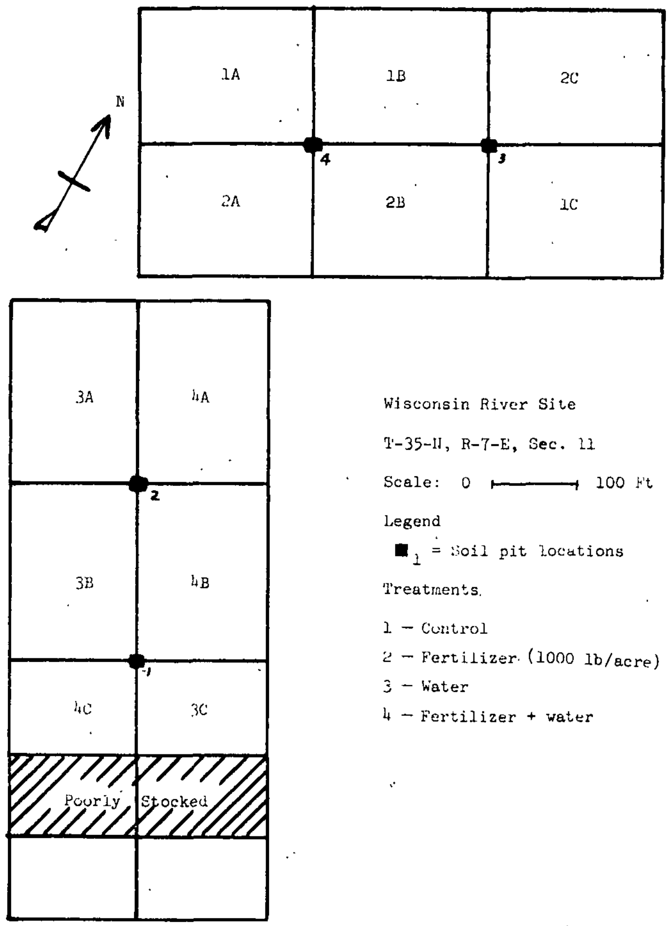


Figure 13. Arrangement of Treatments and Replications in Silvicultural Trial IV Location on Owens-Illinois, Inc. Lands Near Tomahawk, Wisconsin

The treatments were applied to the area in 1969 and consisted of control, fertilizer (1000 lb/acre), irrigation, and irrigation + fertilizer. The fertilizer used was a balanced, custom-made fertilizer containing 20% N, 5% P, 10% K, 10% Ca, and 2% Mg. Because of the sandy nature of the soil, the nitrogen supplied was 1/2 slow-release, urea-type nitrogen and 1/2 ammonium nitrate. The described fertilizer treatment was reapplied in the spring of 1973. The only change in 1973 was to increase the level of K to 20%.

The irrigation equipment used to supply water to the irrigated portion of the trial consisted of a gasoline engine and pump, portable aluminum pipe, and eleven high-volume (40 gallons/min) sprinkler heads mounted on 20-foot risers. Irrigation water was pumped from the Wisconsin River and the times of application were based on soil moisture measurements and weather information. A delay in receiving permission to use water from the Wisconsin River in 1969, problems with the irrigation pump during July, 1970 and adequate rainfall in 1971 resulted in less irrigation water being applied than was originally planned. Supplementary water totaled 4.4 inches/acre for 1969, 3.7 inches for 1970, 5.5 inches for 1971, 6.4 inches for 1972, 8.7 inches for 1973, 6.6 inches for 1974 and 8.3 inches for 1975.

Original Stand Volume and Early Growth

Detailed information regarding the original stand volumes on the area was taken in order to be able to properly evaluate the results of the applied treatments. Four 1/50-acre permanent subplots were located in each plot (replication of a treatment). Numbers and size of quaking aspen suckers were determined and these data and future remeasurements will be used to evaluate treatment effects. The average volume of the six-year-old sucker stand at the start of the study was 160 cu ft/acre. Growth measurements were not made the first fall after the treatments were applied. Measurements made in the fall of 1970 and the fall of 1971, the second and third years after treatment, revealed there had been significant increases in height, diameter, and total volume due to treatments. The increased growth appeared to be due primarily to the irrigation treatment and irrigation x fertilizer interaction. By the fall of 1972, the fourth growing season after the start of the treatments, total growth (increase in volume) was 200 cu ft/acre on the control plots while growth for the fertilizer, irrigation, and fertilizer + irrigation treatments was 230, 327, and 448 cu ft/acre, respectively.

Fertilizer* was reapplied in 1973 and growing conditions were about average. Despite adequate growing conditions there was an across-the-board reduction in growth for all treatments, apparently the result of natural thinning that was under way at the site.** After the 1973 season (fifth growing season since treatment), the overall average growth for the five years is 48, 55, 82, and 110 cu ft/acre/year for the control, fertilizer, irrigation and fertilizer + irrigation treatments. This amounted to a growth response (increase) of 13, 70, and 127%.

1975 Measurements

Growth measurements were not made in 1974 and the measurements made in 1975 provide an estimate of the changes in tree size and volume that have occurred during the 1974 and 1975 growing seasons, the sixth and seventh years since the start of the study. Table XXX summarizes the measurement data taken since 1968 and Table XXXI summarizes the statistical comparisons made on the 1975 measurements.

Growing conditions were near normal during 1974 and 1975. A total of 6.6 inches of supplementary water was applied in 1974 and 8.3 inches in 1975 to keep moisture conditions near optimum. Earlier described across-the-board thinning that seemed to be developing in 1973 continued with the greatest reduction in numbers of trees occurring on the fertilized plots and least reduction on the "irrigation only" treated areas. Height growth, diameter growth and total volume response drastically changed on this trial during 1974 and 1975. Growth response during the first five years after treatments were initiated was due primarily to irrigation and fertilizer increased growth only when added in combination with

*Level — 1000 lb/acre of $N_{20}P_5K_{20}Ca_{20}Kg_4$.
**The "thinning effect" of fertilization which was noted in both this trial and ST-V, could be expected to result in increased soil moisture for the surviving trees. Continued root system development could also be expected to increase the level of available moisture.

TABLE XXX

SILVICULTURAL TRIAL IV
NUMBER OF TREES, SIZE, BASAL AREA, AND VOLUME DATA FOR LIVE TREES ONLY

Treatment	Year	Number Trees/Acre	Av. Ht., ft	Av. DBH, in.	Basal Area per Acre, ft^2	Dry Wt., per Acre, lb[a]	Estimated Volume per Acre,[a] cu ft
Control	1968	5854	11.6	0.77	19.8	3452	151
	1970	6325	12.7	0.86	28.4	5116	223
	1971	6546	13.2	0.95	35.9	6423	280
	1972	6592	13.5	1.05	44.5	8033	351
	1973	6029	14.9	1.10	45.9	8977	392
	1975	4542	17.2	1.34	49.1	10417	455
Fertilizer	1968	5671	11.2	0.69	17.2	3688	161
	1970	6191	12.7	0.91	31.3	5535	250
	1971	6083	13.3	1.01	38.6	6845	311[c]
	1972	5854	14.4	1.16	48.6	8975	391
	1973	5329	15.9	1.22	48.9	9935	434
	1975	3812	19.5	1.57	56.7	13039	569
Irrigation	1968	5517	12.2	0.80	21.2	3818	167
	1970	5846	14.0	0.96	33.8	6490	283
	1971	6025	14.8	1.07	43.6	8614	376
	1972	6029	15.9	1.19	55.0	11327	494
	1973	5571	17.6	1.25	56.6	13216	577
	1975	4691	19.4	1.49	68.1	16555	723
Fertilizer + irrigation	1968	5517	12.3	0.81	21.0	3719	162
	1970	6233	13.8	1.02	40.3	7468	326
	1971	6237	15.0	1.19	55.4	10923	477
	1972	5554	16.8	1.39	66.5	13969	610
	1973	4746	19.1	1.54	69.8	16265	710
	1975	3190	23.0	2.04	80.0	21107	921
South control[b]	1968	5662	12.4	0.84	25.2	4553	199
	1970	5575	12.8	0.88	26.8	4924	215
	1971	5900	13.2	0.97	34.4	6240	272
	1972	5787	14.0	1.07	40.8	7686	335
	1973	5437	15.2	1.14	43.3	8652	378
	1975	4112	17.8	1.41	47.8	10508	459

[a]Dry weight and volume based upon live stem wood only, taken to a minimum top diameter of 0.5 inch. Trees less than 0.5 inch were excluded. Dry weight and estimated volume based upon volume and weight tables by Bella (19).

[b]Additional control replication located on the south portion of the test area.

TABLE XXXI

SILVICULTURAL TRIAL IV
STATISTICAL COMPARISON OF TREATMENT MEANS USING DUNCAN'S MULTIPLE RANGE TEST

Treatment	No. Trees per Acre	1974-75 Change No. Stems per Acre	Av. Total Ht., ft	1974-75 Ht. Growth, ft	Av. DBH, in.	1974-75 Diam. Growth, in.	Total Vol., cu ft/acre	1974-75 Vol. Growth, cu ft/acre
Control	4542^{x}	-1487^{x}	17.2^{x}	2.3^{x}	1.34^{x}	0.23^{x}	455^{x}	63^{x}
Fertilizer	3812^{y}	-1516^{x}	19.5^{y}	3.6^{y}	1.57^{x}	0.35^{xy}	569^{x}	135^{xy}
Irrigation	4691^{x}	-880^{y}	19.4^{y}	1.8^{x}	1.49^{x}	0.25^{x}	723^{xy}	146^{xy}
Fertilizer + irrigation	3190^{z}	-1555^{x}	23.0^{z}	3.9^{y}	2.04^{y}	0.50^{y}	921^{y}	211^{y}
"F" Test[a] for treatments:	S	S	S	S	S	S	S	S

[a]Analysis of variance "F" test for treatments. "S" indicates values significant at the 5% level of probability, "NS" — nonsignificant test.

[xyz]Duncan's Multiple Range Test; means followed by a common superscript are not significantly different.

irrigation. During 1974 and 1975, height and diameter growth was greater on the "fertilizer only" than on the "irrigation only" treated areas. Volume growth was similar for the two treatments because of the greater numbers of stems per acre on the irrigated areas. Best height, diameter and volume growth continued to occur on the area receiving both periodic fertilization and annual supplemental irrigation. The reason for the increased response to fertilization is not clear but it appears to be due to reduced levels of N and K on the nonfertilized plots and adequate soil moisture levels during 1974 and 1975 which made reasonable growth response possible.

After the 1975 growing season, the average growth rate during the seven-year period was 43, 58, 79 and 108 cubic feet/acre/year for the control, fertilizer, irrigation and the fertilizer plus irrigation treatments. This represents an overall volume growth response (increase) of 34, 83, and 149% over growth on the untreated control areas.

Levels of Nutrients in Leaves

Leaf samples were collected from all plots in Silvicultural Trial IV in August, 1975. This marks the seventh fall that leaf samples have been collected and analyses completed in an effort to evaluate the effectiveness of the fertilizer treatment and to monitor changes in the nutrient levels following treatment. Summarized in Table XXXII are the results of the 1975 analyses. Statistical comparisons using analysis of variance and Duncan's Multiple Range Test demonstrated that, for the nutrients examined (N, P, K, Ca, and Mg), only in the case of nitrogen were there greater levels in the leaves of the fertilized trees than in the non-fertilized trees. These results indicate a declining effect of the fertilizer that was applied in June of 1973. Table XXXIII summarizes leaf nutrient analysis data for Silvicultural Trial IV for the past seven yars. This overview indicates that nitrogen and potassium are the two elements most influenced by the fertilizer treatments (applied 1969, 1973) and that N and K are very likely the elements responsible for the growth increases that have been obtained.

TABLE XXXII

SILVICULTURAL TRIAL IV
1975 LEVELS OF NUTRIENTS IN LEAVES

Treatment	Nitrogen, %	Phosphorus, %	Potassium, %	Calcium, %	Magnesium, %
Control	2.36[x]	0.16	0.74	1.26	0.31
Fertilizer	2.51[y]	0.19	0.91	1.48	0.27
Irrigation	2.58[y]	0.17	0.85	1.22	0.26
Fertilizer + irrigation	2.92[z]	0.18	0.75	1.07	0.25
"F" Test[a] for treatments:	S	NS	NS	NS	NS

[a]Analysis of variance "F" test for treatments. "NS" indicates nonsignificant test.

Summary

Height, diameter and volume growth response has been obtained as a result of the treatments applied. Growth on the control plots has been less than anticipated and indicates the site quality is lower than originally recognized. Treatment growth response has varied from year to year, depending on weather conditions and the time elapsed since fertilization. Stand thinning due to overcrowding, hail damage and rabbit injury has also influenced treatment response. Volume growth peaked in 1971 for the fertilization plus irrigation plots and in 1972 for the control, fertilizer, and irrigation plots. Growth of all treatments decreased in 1973 and increased again during 1974 and 1975. For the first five years, growth was greatest on the fertilization plus irrigation plots and improved growth appeared to be due primarily to increased soil moisture.

TABLE XXXIII

SILVICULTURAL TRIAL IV[a]
LEVELS OF NUTRIENTS IN LEAF SAMPLES

Treatment	Year	N, %	P, %	K, %	Ca, %	Mg, %
Control	1969	2.71	0.21	0.71	1.38	0.25
	1970	2.43	0.22	0.61	1.48	0.34
	1971	2.42	0.18	0.85	0.92	0.21
	1972	2.55	0.18	0.77	1.06	0.16
	1973	2.68	0.21	0.93	1.23	0.24
	1974	2.58	0.17	0.82	1.14	0.18
	1975	2.36	0.16	0.74	1.26	0.31
Fertilizer	1969[b]	3.27*	0.27*	1.50*	1.09	0.36
	1970	2.46	0.20	0.76*	1.44	0.25*
	1971	2.65*	0.17	0.73	0.83	0.18
	1972[b]	2.76	0.19	0.84*	1.11	0.14
	1973[b]	3.18*	0.21	0.95	1.28	0.28
	1974	2.90	0.19	1.00	1.09	0.19
	1975	2.51	0.19	0.91	1.48	0.27
Irrigation	1969	2.59	0.20	0.72	1.26	0.31
	1970	2.42	0.25	0.89	1.64	0.24
	1971	2.75	0.19	0.87	1.21	0.21
	1972	2.95	0.23	0.66	1.52	0.23
	1973	2.70	0.22	0.91	1.37	0.27
	1974	2.65	0.21	0.84	1.23	0.25
	1975	2.58	0.17	0.85	1.22	0.26
Fertilizer + irrigation	1969[b]	3.19*	0.24*	1.09*	1.30	0.26
	1970	2.55	0.22	0.68	1.35	0.27*
	1971	2.73*	0.20	1.10*	0.91	0.19
	1972[b]	3.11*	0.23	0.75	1.27	0.18
	1973[b]	3.58*	0.24	1.07	1.25	0.26
	1974	2.88	0.19	0.83	1.00	0.18
	1975	2.92*	0.18	0.75	1.07	0.25

[a]Percent on dry weight basis.

[b]Years fertilizer applied.

*Asterisks indicate treatments significantly different than the control.

During 1974 and 1975, height and diameter growth was greater on the fertilized plots than on the irrigation plots and overall response, after fertilizer was reapplied in 1973, appeared to be due to an approxiately equal contribution of fertilizer and water. Nitrogen and potassium appear to be the elements responsible for the growth increases due to fertilization. Another important aspect of the study was the apparent thinning effect of fertilization, suggesting an additional advantage of the use of fertilization as an aspen management technique. Overall total growth was 304, 408, 556 and 759 cubic feet or 43, 58, 79, and 108 cubic feet/acre/year for the control, fertilizer, irrigation, and the irrigation plus fertilization treatments. This translates in terms of increased growth into 34, 83, and 149% greater growth than that on the control plots.

Plans

Irrigation and fertilization treatments on ST-IV will be discontinued. No more measurements of the trial are planned, except for possible remeasurement of the trial in 1980. Funds permitting, the influence of increased growth rate on wood quality will be evaluated in 1976.

Silvicultural Trial V

Silvicultural Trial V was established in the fall of 1969 on a 10-acre tract of 18-year-old aspen on Owens-Illinois, Inc. land. The area is located near the Willow Flowage (Section 8, T-37-N, R-5-E, Oneida County). The objectives of this trial are twofold: (1) to determine the total yield of a 15- to 20-year-old aspen stand and (2) to demonstrate the early growth potential of an aspen sucker stand in terms of its natural development and development when fertilized and irrigated.

In 1969 the first objective was met and reported in a Genetics & Physiology Note (8). The 18-year-old stand was clear cut and all stems processed into chips or roundwood and the actual weights determined at the Owens-Illinois woodyard scale. The actual yield of ovendry wood, with about 17-18% bark included, amounted to 42,400 lb/acre at age 18 as compared to a predicted total wood yield of 40,400 lb/acre at age 35.

The study presently under way on the area is designed to meet the second objective listed above. After the area was harvested, the 10-acre area was used as the site of a fertilization and irrigation study. A three-replicate, randomized block, split-plot design trial was laid out on the area and the resulting aspen sucker stand that developed served as the test materials upon which growth measurements were taken. The trial was fertilized in 1970, again in 1975 and the growing season irrigation treatments were started the summer of 1970.

Progress Report One (p. 67-77) discusses treatment techniques and describes in detail the changes that have taken place on the site during the first five growing seasons. Provided is information on height and diameter growth, changes in number of stems per acre and volume growth. Growth measurements were not made in 1975. However, in addition to fertilizing the designated plots (1000 lb/acre $N_{20}P_5K_{20}Ca_{20}Mg_4$), the area was irrigated and leaf samples collected in August. Observation of the test area during this past summer indicated growth this past year has been about average and the natural thinning process that was under way in 1974 was continuing but at what appears to be a somewhat slower pace. The trial will be measured again in 1976.

Level of Nutrients in Leaves

Leaf samples were again taken at the end of the 1975 growing season. Of particular interest are the changes that occurred in leaf nutrient levels the first growing season after fertilization. Summarized in Table XXXIV, in addition to the 1975 data, are the results of leaf nutrient uptake data for the years 1970 through 1974. Analysis of variance and Duncan's Multiple Range Test were run on the 1975 nutrient uptake data. Levels of nitrogen increased as the result of fertilization to the point that they were significantly greater on the "fertilized" and "fertilizer plus irrigation" plots. Potassium uptake appears to have increased as the result of the 1975 fertilization but differences were not quite large enough to be significant. None of the other nutrients under investigation increased to the point where they were significantly different from the leaf samples from the untreated areas.

Plans

Temperature, rainfall and soil moisture will continue to be monitored and supplemental water will be added as required to keep soil moisture near optimum. The test trial will be measured in 1976 and leaves collected and evaluated for nutrient uptake in late August.

CONVERSION OF OPEN AREAS AND NORTHERN HARDWOODS STANDS TO IMPROVED ASPEN

Aspen hybrids are capable of occupying low quality northern hardwood sites and in most cases are able to grow at a rate greater than the original hardwoods. However, it should be recognized that there is a lower limit to the site quality suited for improved aspen. A minimum level of nutrients and moisture availability must be present to assure survival and growth. The diagram in Fig. 14 presents the soil nutrient requirements necessary for good aspen growth in the Lake States. The inner circle establishes the minimum soil nutrients necessary for aspen growth. The outer circle delineates the near optimum levels of soil nutrients, beyond which growth response would not be expected from

TABLE XXXIV

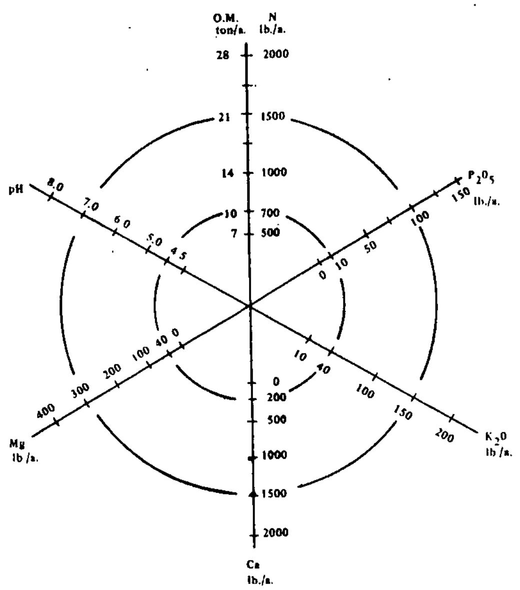
SILVICULTURAL TRIAL V
LEVEL OF NUTRIENTS IN LEAF SAMPLES — 1970-1975[a]

Treatment	Year	N, %	P, %	K, %	Ca, %	Mg, %
Control	1970	2.69	0.24	0.63	1.52	0.35
	1971	2.43	0.18	0.71	1.02	0.24
	1972	2.64	0.19	0.64	1.40	0.22
	1973	2.83	0.23	0.86	1.38	0.33
	1974	2.58	0.20	0.79	1.23	0.23
	1975	2.40	0.17	0.74	1.03	0.22
Fertilizer	1970	3.07*	0.24	0.83	1.23	0.33
	1971	2.86*	0.20	0.98*	1.02	0.19
	1972	2.84	0.19	0.80*	1.23	0.16
	1973	2.81	0.23	1.06	1.44	0.28
	1974	2.49	0.19	0.91	1.16	0.20
	1975	2.82*	0.19	1.01	1.10	0.19
Irrigation	1970	2.76	0.23	0.87	1.52	0.30
	1971	2.44	0.18	0.82	1.19	0.22
	1972	2.59	0.19	0.74	1.24	0.21
	1973	2.85	0.21	0.90	1.53	0.30
	1974	2.51	0.17	0.90	1.21	0.19
	1975	2.26	0.19	0.73	1.08	0.21
Fertilizer + irrigation	1970	3.02*	0.23	0.83	1.41	0.27
	1971	2.91*	0.21	1.03*	1.21	0.21
	1972	2.98	0.19	0.82*	1.06	0.21
	1973	2.75	0.19	1.00	1.46	0.29
	1974	2.56	0.20	0.99*	1.07	0.22
	1975	2.87*	0.19	0.96	1.04	0.21

[a]Values are averages of the three replications of each treatment. The percentages are the percentages of the ovendry weight.

*Asterisks indicate treatments significantly different than the control.

fertilization. One factor must be considered when using the chart and that is the available moisture. Without minimum moisture, the nutrient levels of a given soil have little effect on growth.



NUTRIENT REQUIREMENTS LAKE STATES ASPEN SOILS

Figure 14. Illustrated are the Minimum (Inner Circle) and Near Optimum (Outer Circle) Levels of Soil Nutrients for Growth of Aspen. Amounts Indicated are the Weighted Average Values for the Top 24 Inches

The intent of site conversion is to utilize a site's potential, shifting from a low production basis to a higher production basis. Where a site is producing suitable growth, there would be no need to consider conversion.

The results from several site conversions in Wisconsin and Michigan have been very encouraging. Overall growth and survival has been good. Competition from native vegetation has been minimal, with one possible exception on a site near Mesick, Michigan. Further discussion of this site can be found under the heading Silvicultural Trial XII.

An area near Tomahawk, Wisconsin on Owens-Illinois, Inc. lands was clearcut during the late summer and fall of 1970 and an adjoining parcel was cut in 1971. The two parcels make up the Lost-Alber Road Test Area and consist of four plantings, each demonstrating a conversion technique. A temporary deer fence was placed around the area but proved to be rather ineffective. The topography was such that in many locations gaps existed beneath the fence allowing the deer to enter. The four trials at the Lost-Alber Road Area are ST VI, VII, VIII, and IX.

Silvicultural Trial VI

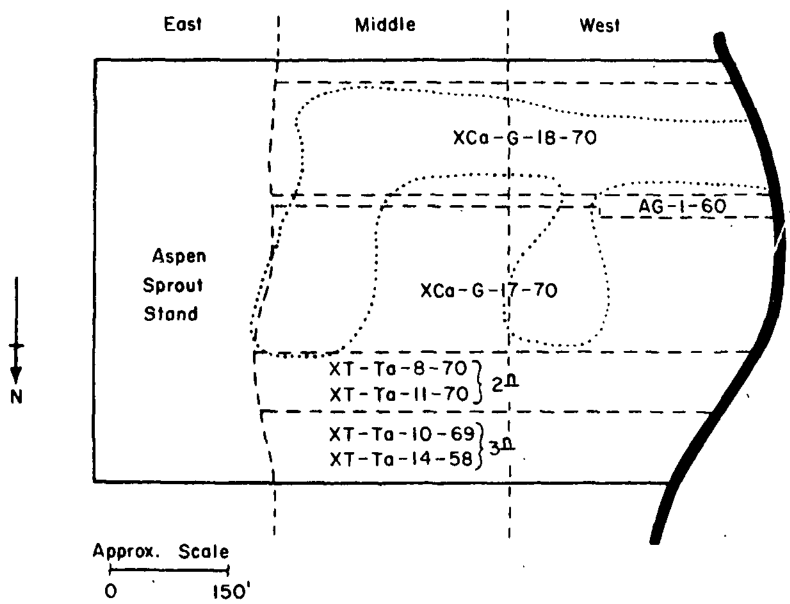
ST-VI was planted the spring of 1971 following a fall clearcut. Two triploid materials were planted: a clonal selection from cross XT-Ta-14-58 and seedlings from cross XT-Ta-10-69. The remaining materials were diploid and included a natural hybrid clonal selection, AG-1-60, and seedlings from four crosses: XT-Ta-8-80, XT-Ta-11-70, XCa-G-17-70, and XCa-G-18-70*. One-third of the trial demonstrates natural aspen regeneration and the remaining two-thirds are planted with improved aspen. Reproduction from native species has been unable to match the growth from the planted stock. The exceptions are root sprouts from native aspen. The hybrids are competing well with the aspen and in several instances are out-growing them in both height and diameter. However, the intent is not to convert vigorous, natural aspen stands to hybrid aspen.

Several individuals in the "canescens x bigtooth" crosses have shown growth in excess of 19 feet after 5 years. The "quaking x tremula" triploids have not done as well, although trees with heights over 15 feet were noted. Figure 15 illustrates the growth of a "canescens x bigtooth" hybrid and a "quaking x tremula" triploid hybrid at the end of the fifth year and the competing vegetation around them. The triploids were planted in an area with a high water table and very poor drainage. Survival is primarily around the edges of the saturated area and does not reflect the full potential of this cross. A diagram of the trial is given in Fig. 16.

*See Appendix for an explanation of the experimental tree code system.

Figure 15. Two Five-Year-Old Materials in Silvicultural Trial VI at the Lost-Alber Road Test Area. The Hybrid on the Left is from Cross XCa-G-18-70 and is Over 19 Feet in Height. The Individual on the Right is a Triploid Hybrid over 17 Feet in Height. Early Growth of the Triploid Materials was Hampered by Wet Soils and Heavy Vegetative Competition

Figure 16. Diagram of Silvicultural Trial VI Giving the Location of Planted Materials and the Three Types of Areas: Left — Aspen Sprout Stand, to the West the Planted Compartments (West and Middle) Which Include the Skid Road Compartment (Within Dotted Lines)



Silvicultural Trial VII

ST-VII is also located on the Lost-Alber Road Test Area. It was planted in May, 1972 following a clearcut in 1970 and 1971. The area has a relatively high water table on the north end with wet areas on the east and northwest corner. The heaviest densities of natural aspen reproduction developed near these wet areas and were not planted. Figure 17 illustrates ST-VII.

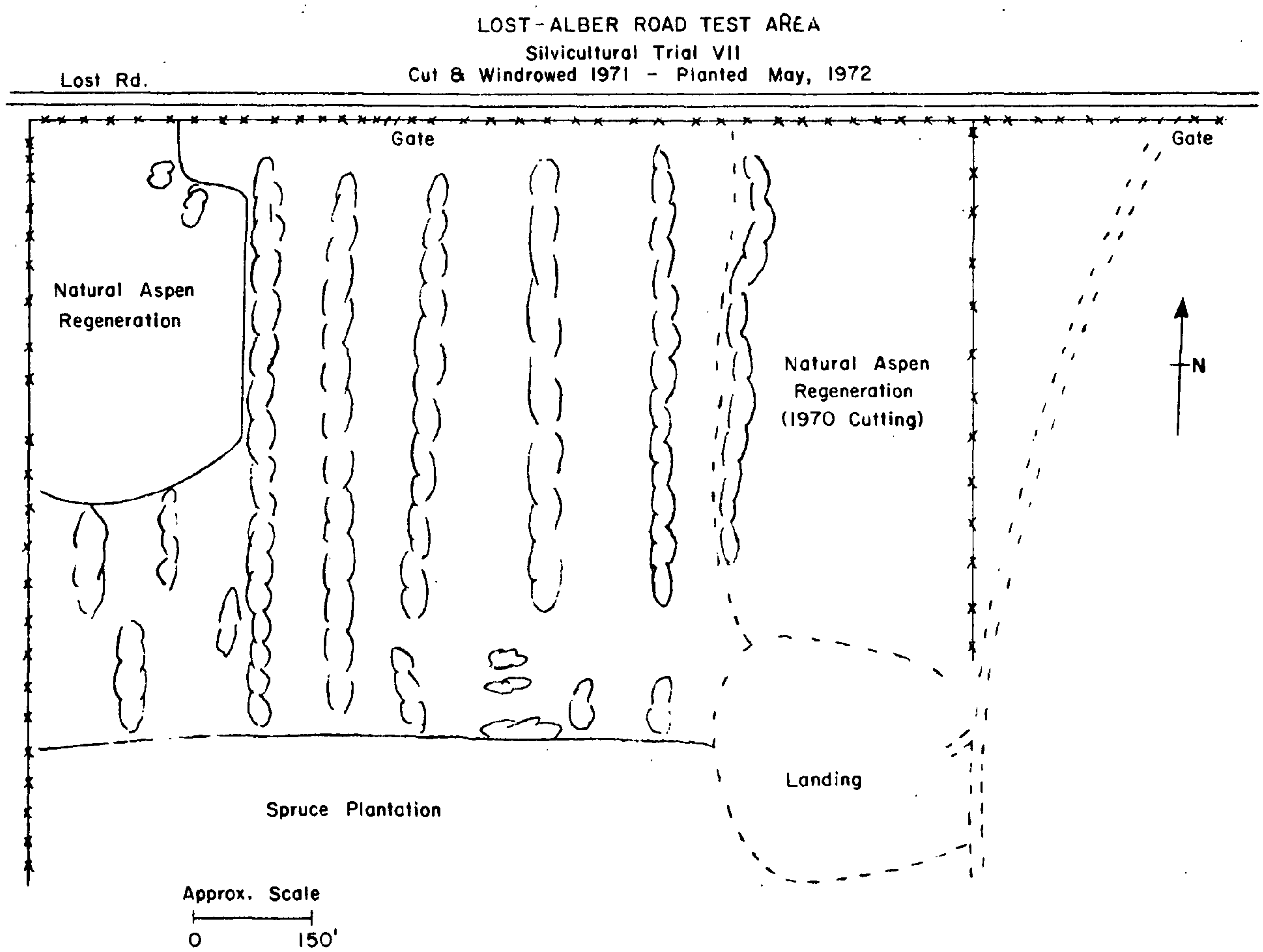


Figure 17. Presented is a Diagram of Silvicultural Trial VII Indicating Slash Windrows (North-South Rows) and the Area, Excluding the Natural Aspen Regeneration, Planted to XCa-G-19-71

The slash that remained after harvest was windrowed prior to planting. A spacing approximating 9 x 9 feet was used as a guideline in hand planting the material, XCa-G-19-71, a "canescens x bigtooth" hybrid on the area.

Average height growth for the trial remained at the same height as 1974: 5.5 feet. Many of the stems present in 1974 were alive but injured by mice and rabbits. The 1975 growing season saw the death of the injured stems but most produced new suckers from below the injury or from the root system near the root collar. The subsequent sprouts are vigorous but below the height growth of the stems they are replacing. Several uninjured individuals are over 14 feet in height and 1 inch diameter bh (Fig. 18). These individuals are well established and will be present for future harvests as will many of the more vigorous sprouts now present.

Figure 18. Cross XCa-G-19-71 at ST-VII on the Lost-Alber Road Test Area. The Trial is a 4-Year-Old Conversion Planting with Individuals Over 14 Feet

Silvicultural Trial VIII

ST-VIII is an old field site employing a wide spacing technique. The rows are 25 feet apart with six-foot spacing within rows. Cultivation was applied to each side of a row in one direction, leaving approxiately a 12-foot-wide uncultivated strip between rows. This strip will be stocked when the planted materials are harvested and allowed to sprout. A diagram of the area is shown in Fig. 19.

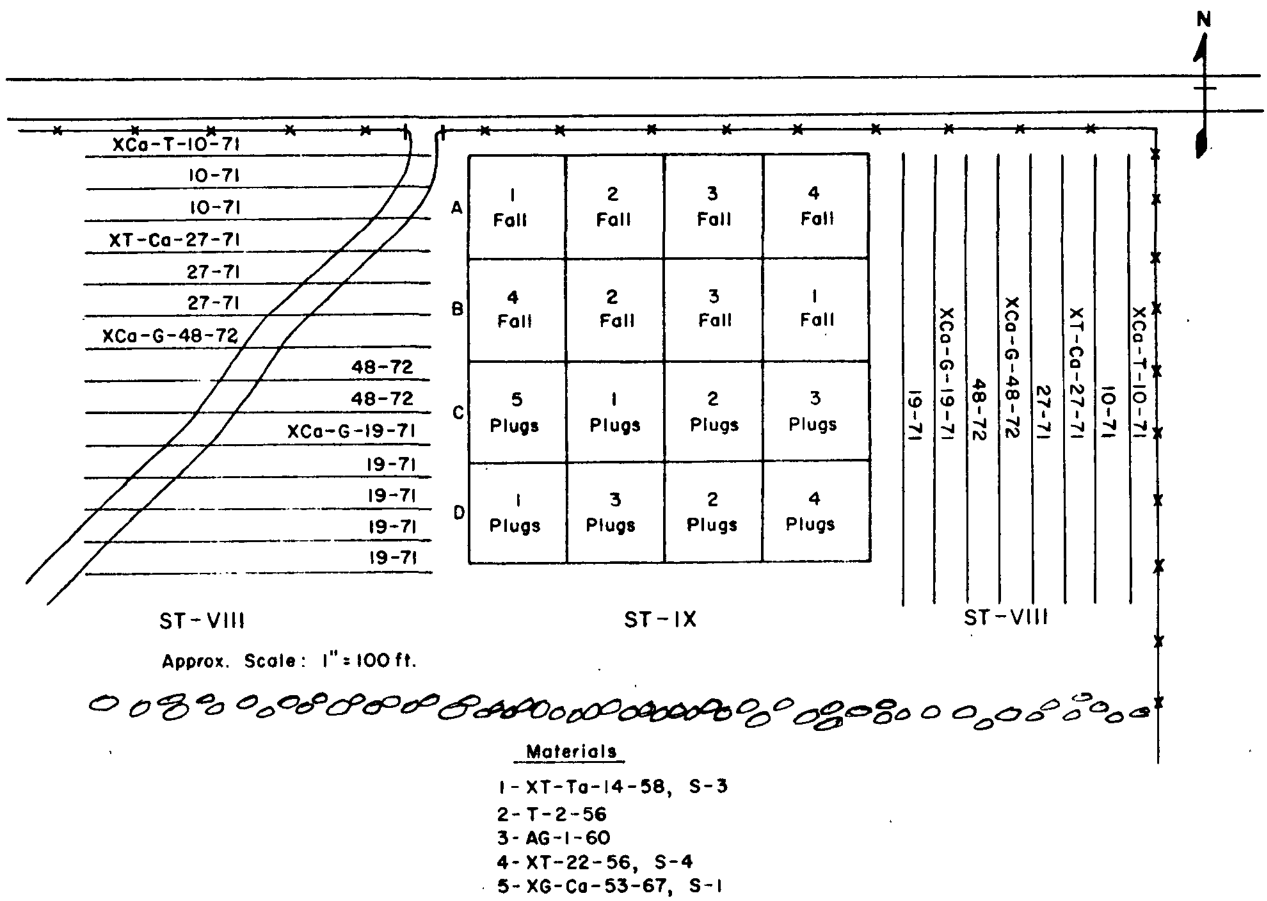


Figure 19. Lost-Alber Road Test Area, Silvicultural Trials VIII and IX

The soil has an extreme number of large stones that have hampered all cultivation attempts. As a result, vegetative competition brought the trial to a virtual standstill. A herbicide treatment was applied in June to every other row using a small hand sprayer and a stovepipe shield to protect individual trees.

Each tree within the selected row had a two-foot diameter circle sprayed around it. Response to this treatment has not been evaluated, although vegetative control appears to be good. A small number of trees were killed inadvertently during the treatment. Aspen is susceptible to the particular herbicide used at levels of 1/4-lb per acre. Most of the contamination was brought about by residue on the shield and hands of the men placing the trees in the shield and from the sprayed vegetation that contacted the trees after the shield was removed. Again, the losses appear to be minor.

Growth measurements for 1975 revealed a high mortality in ST-VIII. Several of the losses can be attributed to the herbicide application but the majority are the result of repeated mouse and rabbit girdling and deer browsing. The injuries to the bark and branches may have weakened the trees and opened the way for secondary attacks by other organisms. Close observation is warranted next summer to evaluate the effectiveness of the herbicide and to determine the extent and causes of the mortality.

Silvicultural Trial IX

ST-IX is a demonstration planting of selected clonal materials on an old field site (Fig. 19). One half of the trial was planted in July, 1973 using "plugs"* of green (nondormant) planting stock. The second half was planted in October of 1973 with bare-rooted dormant stock. Numerous large stones throughout the field limited the effectiveness of preplanting treatments and made cultivation following planting very difficult. Vegetative competition increased in 1974 and cultivation attempts in 1975 to reduce it were ineffectual. As in ST-VIII, a herbicide treatment, using a small sprayer and stovepipe shield, was applied to individual

*Rooted root sprouts growing in elongated, bullet-shaped cavities created in styrofoam blocks. The roots, in filling the soil of the cavities, form bullet-shaped "plugs" when removed for planting.

trees in a two-foot diameter circle. The effectiveness of this treatment will not be known until the next growing season.

Growth of the trial was virtually at a standstill this past year. Many of the original stems were girdled by mice or browsed by deer during the winter of 1975. Extensive sprouting occurred, maintaining survival but limiting increased growth. The sprouts brought the average height back up to and somewhat over the average heights of 1974. Figure 20 shows a one-year-old "alba x bigtooth" sprout. It is essentially a one-year-old cane on a two-year-old root system. If this particular stem and others like it are not girdled this winter, they should be able to place enough diameter growth on next year to withstand future animal damage.

Figure 20. Winter Mouse Girdling Killed Many Trees to the Groundline in ST-IX. Illustrated is a 7.5-Foot Sprout After One Summer's Growth. The Resultant Tree is Actually a One-Year-Old Sprout on a Two-Year-Old Root System

Silvicultural Trial XII

ST-XII is located in Manistee County, Michigan on the Betsie River State Forest, T-23-N, R-13-W, Section 1, NE 1/4, SW 1/4 and is 23-1/2 acres in size (Fig. 21). The trial is a cooperative planting with the Michigan DNR and demonstrates the conversion of a medium quality hardwood site to improved aspen. The Michigan DNR prepared the site, fenced the area, planted the trees, and has observed and measured the planting. The Institute provided the trees, advice on establishment, and some supervision.

The conversion site was stocked prior to cutting with red maple, white ash, beech, black cherry, and widely scattered bigtooth and quaking aspen. Growth of the red maple on the area indicated that the site index (base age 50) was about 60. Nutrient analysis of soil samples taken in 1973 indicate that the area is somewhat low in phosphorous, calcium, and magnesium and also has a fairly low pH. The seriousness of these lower levels does not appear to be great as they are still within the range of good aspen growth outlined by the diagram in Fig. 14.

The area was planted in the spring of 1974 with two "canescens x bigtooth" hybrids, two "quaking x tremula" triploid hybrids, and one natural and one selected "alba x bigtooth" hybrid clone. The site was clearcut in the fall of 1973 using a hydraulic shear. The resultant slash was windrowed prior to planting. An area of about 3 acres with the lightest slash cover was left untreated and the trees were planted in the slash.

To reduce expected deer pressure, a medium-weight poultry fence was placed around the area. Part of the planting was placed outside of the fence to provide a demonstration of the effects of deer browsing on the establishment of aspen hybrids. During the first year, deer had browsed 95% of the hybrids; during

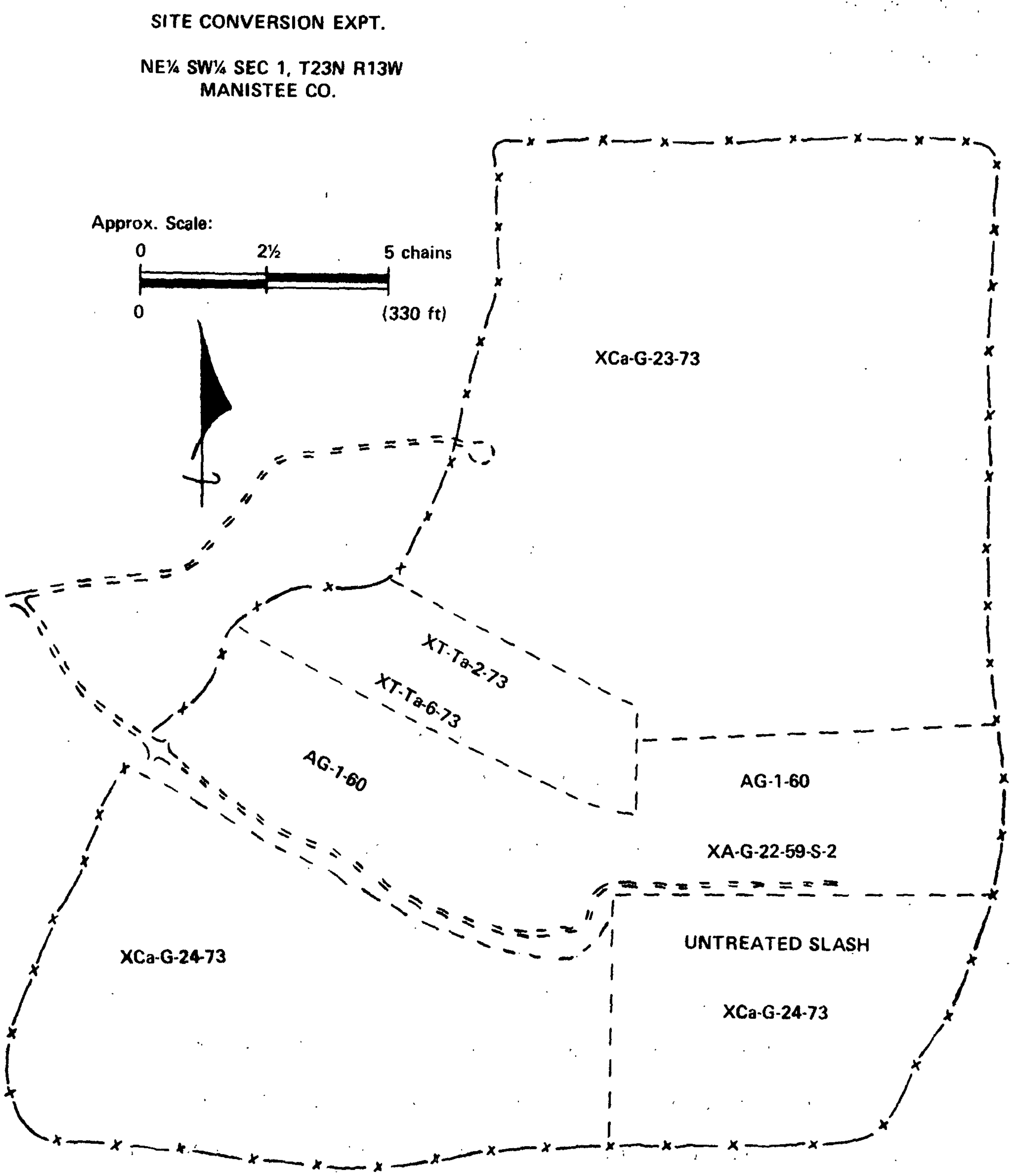


Figure 21. Diagram of ST-XII, a Cooperative Planting with the Michigan DNR. The Area Planted is 23-1/2 Acres

1975, the figure dropped to 54%. Height growth data (Table XXXV) reflects the extent of the deer browsing during 1974 and 1975.

TABLE XXXV

SILVICULTURAL TRIAL XII
FIRST AND SECOND-YEAR GROWTH AND SURVIVAL

Material[a]	1974 Av. Height, ft	1974 Survival, %	1975 Av. Height, ft	1975 Survival, %
AG-1-60	3.3	96	5.3	88
XA-G-22-59, S-2	3.2	100	5.3	98
XG-G-23-73[b]	2.5[b]	--	3.6[b]	--
XG-G-23-73	3,0	98	5.1	97
XCa-G-24-73	3.2	98	5.3	100
XT-Ta-2-73	2.2	98	4.1	93
XT-Ta-6-73	2.0	100	3.8	94

[a]See Appendix for code used in describing test materials.
[b]Exposed to deer browsing outside of fenced area.

Total growth for all materials within the fenced area averaged 4.8 feet (two growing seasons) with 95% survival. Table XXXV presents growth and survival data for each material. Several individuals have produced growth of over ten feet at the end of the second growing season and many stems are over seven feet (Fig. 22). The triploid crosses (XT-Ta-2-73 and XT-Ta-6-73) are showing the slowest growth at this point, but it is not altogether unexpected. The parents of these two materials are from northern sources and the progeny tend to set up buds and harden off early (August 1 in 1974). The triploid materials also tend to produce moderate height growth during the first few growing seasons and then show larger increases in height growth after the initial establishment period. The vigor and appearance of the triploid materials at

ST-XII during 1975 indicates that increased growth during the 1976 growing season should be expected.

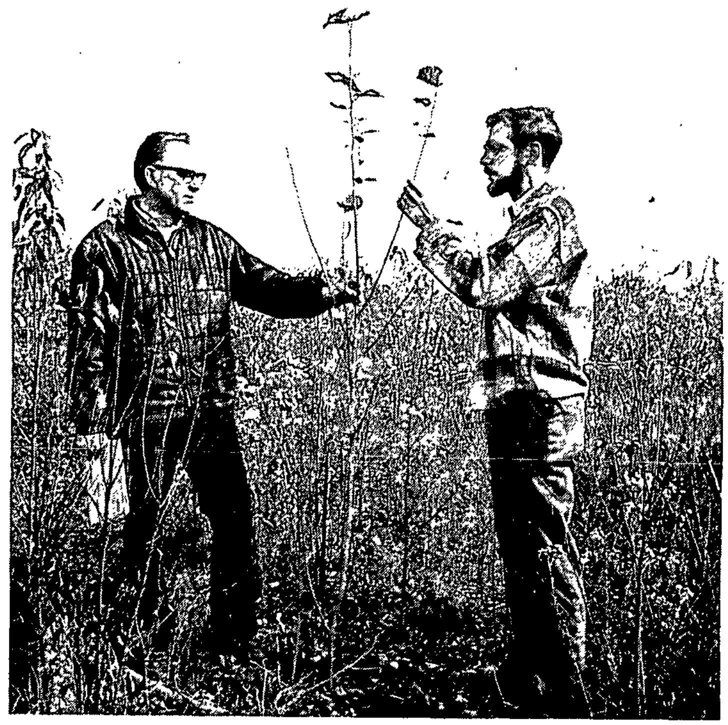


Figure 22. A Two-Year-Old "Canescens x Bigtooth" Hybrid on a Medium Quality Northern Hardwood Conversion Site in Lower Michigan (ST-XII). Note the Dense Black Cherry Reproduction That has Provided the Major Competition

Figure 22, besides illustrating the growth and form of a "canescens x bigtooth" hybrid, also displays the vigorous competition provided by black cherry seedlings. Data supplied by the Michigan DNR indicates that 64% of all planted materials are above the competition. It is expected that the hybrids will continue to compete and for the most part stay ahead of the black cherry. Other returning natural vegetation has posed no competitive problem.

PLANS

There will be a modest reduction in overall activity during the coming year with the discontinuation of the irrigation of Silvicultural Trials III and IV (ST-III and ST-IV) and as a result of a slight reduction in the number of field trials being measured during the coming year. Principal activities will include the production of hybrid seed and seedlings for cooperator plantings, the propagation of selected parent trees for the planned "flowerbud" arboretums (IPC and cooperator) and the irrigation of ST-V and ST-X. The fertilization of ST-X will be completed and, funds permitting, the effect of increased growth on wood quality (ST-IV) will be investigated. Also planned is an economic analysis of the possibilities of fertilizing and irrigating hybrid aspen.

Fall field measurements and leaf nutrient analyses will be made of ST-V, ST-VI, ST-VII, ST-VIII, ST-IX, ST-X, ST-XI, and ST-XII. In addition, measurements will be made on approximately twenty of the earlier established aspen genetics field plantings.

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LITERATURE CITED

1. Einspahr, D. W. Colchicine treatment of newly formed embryos of quaking aspen. Forest Sci. 11:456-9(1965).

2. Winton, L., and Einspahr, D. W. Tetraploid aspen production using unreduced triploid pollen. Forest Sci. 16:180-2(1970).

3. Müntzing, A. The chromosomes of a giant Populus tremula. Hereditas 21:383-93(1939).

4. Nilson-Ehle, H. Über eine in der Natur gefundene Gigasform von Populus tremula. Hereditas 21:379-82(1936).

5. Winton, L. Squash preparations for counting aspen chromosomes. Genet. Physiol. Notes 5, Inst. Paper Chem., Appleton, Wis., 1968.

6. Roach, B. A. Management of upland central hardwoods on a pulpwood rotation. Am. Pulpwood Assoc. Tech. Paper 64-22:(7.01), APA Quarterly:20-24, 1964.

7. Smith, H. D. Decision-making under uncertainty: should hardwood plantations be established? N.C. State Univ., School of Natural Resources Tech. Rept. No. 49, 1973. 62 p.

8. Manthy, R. S., Rannard, C. D., and Rudolph, V. J. The profitability of red pine plantations. Mich. State Univ., Agr. Expt. Sta. Rept. 11, undated. 11 p.

9. Manthy, R. S. An investment guide for cooperative forest management in Pennsylvania. U.S.F.S. Northeast For. Expt. Sta. Paper NE-156, 1970.

10. Hiley, W. E. Economics of plantations. London, England: Faber and Faber, 1956. 216 p.

11. Buchman, R. E. Growth and yield of red pine in Minnesota. U.S.D.A., Forest Service Tech. Bull. No. 1272, 1962.

12. Wilde, S. A., Mackie, D. J., and Rausch, T. J. Growth in Wisconsin coniferous plantations in relation to soils. Univ. Wis. (Madison) Res. Bull. No. 262, 1965.

13. Eyre, F. H., and Zillgitt, W. M. Partial cutting in northern hardwoods of the Lake States. U.S.D.A., Forest Service Tech. Bull. No. 1076, 1953.

14. Erdmann, G. G., and Oberg, R. R. Fifteen-year results from six cutting methods in second-growth northern hardwoods. North Cent. For. Expt. Sta. Rept. No. NC-100, 1973.

15. Gingrich, S. F. Management of young and intermediate stands of upland hardwoods. Northeastern For. Expt. Sta. Research Paper NE-195, 1971.

16. U.S.D.A., Forest Service. The outlook for timber in the United States. U.S.D.A., Forest Service Forest Resource Report No. 20, October, 1973. 367 p.

17. Gansner, D. A., and Shaudy, E. T. Opportunities for pulpwood growing investment in southeast Ohio. Northeast For. Expt. Sta. Research Paper NE-151, 1969.

18. Duncan, D. B. Multiple range and multiple "F" tests. Biometrics 11:1-42 (1955).

19. Bella, I. E. Estimating aerial component weights of young aspen trees. Canadian Department of Forestry and Rural Development, Forestry Research Laboratory Reports MS-X-12, Nov., 1968.

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APPENDIX I

RED PINE — ECONOMIC ANALYSIS

An alternative that should be considered instead of growing hybrid aspen in Northern Wisconsin is to plant and grow red pine as a source of fiber. The soils of the area are Vilas fine sand and this soil and similar soils have a site index* of 70 (base age 50) for quaking aspen, a site index of about 60 for red pine and are considered to be of only medium quality for growing northern hardwoods. Table XXXVI lists the variables investigated in determining rotation age and rate of return information on red pine. All combinations of the variables listed were run and a summary of the results are given in Tables XXXVII, XXXVIII, and XXXIX. Table XXXVIII illustrates the land expectation values for red pine when establishment costs are $75/acre. Again, as discussed with hybrid aspen, the values in the table represent the amount that could be invested per acre of land and return the investor the interest rate indicated. Under the assumed conditions, only at 4% interest or at 6% interest and high stumpage prices were positive land expectation values obtained. Red pine values are quite sensitive to establishment cost because of the need to carry these costs for such a long period of time. Reduction of establishment cost greatly improves the land expectation values for red pine.

Optimum Rotation Age

Optimum rotation age was not examined extensively but, of the two rotations used, age 30 gave the highest land expectation values at 6, 8, and 10% interest rates (lowest negative values). Rotation age 45 produced higher

*Site index is a measure of the quality of the site and is the height of the dominant and codominant trees at a specified base age, usually either at base age 50 or 100 years.

TABLE XXXVI

ECONOMIC VARIABLES INVESTIGATED — RED PINE AND NORTHERN HARDWOOD

Variables	Values Investigated
— Red Pine —	
Interest rates, %	4, 5, 8, 10
Rotation age, years	30, 45
Stumpage prices, ¢/cu. ft.	5, 10, 15, 20 and variable[a]
Establishment costs, $/acre	50, 75, 100
Growth rate, cu.ft./acre/year[b]	Age 30 — 106 Age 45 — 144
— Northern Hardwoods —	
Interest rates, %	4, 6, 8, 10
Rotation age, years	45
Stumpage price, ¢/cu.ft.	5, 10, 15, 20 and variable[a]
Establishment costs, $/acre	0
Growth rate, cu.ft./acre/year[c]	75, 100

[a] Stumpage price increasing at a 1%/year and 1-1/2%/year.
[b] Age 30 and age 45 rotation age figures based upon mean annual growth figures from (11) and from site index 60, BA 150 ft^2 tables. Values have been adjusted upward by 20% to account for increased yield from whole tree chipping.
[c] Average values based upon growth of upland hardwoods from several authors (13-15) with the figure used representing growth that has been adjusted upward (50 to 100%) to account for increased yield from whole tree chipping.

TABLE XXXVII

LAND EXPECTATION VALUES — RED PINE[a]

Rotation Length, years	Interest Rate, %[b] 4	6	8	10
	Stumpage Price $0.05/cu.ft.			
30	-49.91	-60.04	-62.91	-63.36
45	-42.13	-61.54	-66.07	-66.18
	Stumpage Price $0.10/cu.ft.			
30	18.89	-26.69	-45.38	-53.70
45	22.83	-36.29	-55.61	-61.67
	Stumpage Price $0.15/cu.ft.			
30	87.69	6.65	-27.86	-44.04
45	87.80	-11.04	-45.14	-57.16
	Stumpage Price $0.20/cu.ft.			
30	156.49	39.99	-10.33	-34.37
45	152.76	14.21	-34.67	-52.66

[a]Land expectation values after 90 years of forest management (present worth of future returns). Calculations based upon $50/acre establishment costs and an annual management charge of $2/acre/year.

[b]Anticipated interest rate or return on investment.

TABLE XXXVIII

LAND EXPECTATION VALUES — RED PINE[a]

Rotation Length, years	Interest Rate, %[b] 4	6	8	10
	Stumpage Price $0.05/cu.ft.			
30	-84.99	-90.15	-90.64	-89.88
45	-71.41	-88.36	-91.86	-91.52
	Stumpage Price $0.10/cu.ft.			
30	-16.19	-56.80	-73.11	-80.21
45	-6.45	-63.11	-81.39	-87.09
	Stumpage Price $0.15/cu.ft.			
30	+52.60	-23.46	-55.59	-70.55
45	+58.52	-37.86	-70.92	-82.51
	Stumpage Price $0.20/cu.ft.			
30	121.40	9.88	-38.06	-60.88
45	123.48	-12.61	-60.45	-78.00
	Variable Stumpage Price — 1%/year[c]			
30	--	-42.64	-66.96	-77.19
45	--	-44.69	-74.33	-84.09
	Variable Stumpage Price — 1-1/2%/year[d]			
30	137.80	5.83	-43.50	-64.84
45	184.76	3.01	-55.59	-76.22

[a] Land expectation values after 90 years of forest management (present worth of future returns). Calculations based upon $75/acre establishment costs and an annual management charge of $2/acre/year.

[b] Anticipated interest rate or return on investment.

[c] Variable stumpage, $0.084/cu.ft. ($7.60/cord) starting price compounded at the rate of 1%/year.

[d] Variable stumpage, $0.111/cu.ft. ($10.00/cord) starting price compounded at the rate of 1-1/2%/year.

TABLE XXXIX

LAND EXPECTATION VALUES — RED PINE[a]

Rotation Length, years	Interest Rate, %[b] 4	6	8	10
	Stumpage Price $0.05/cu.ft.			
30	-120.07	-120.26	-118.37	-116.39
45	-100.69	-115.17	-117.64	-116.86
	Stumpage Price $0.10/cu.ft.			
30	-51.28	-86.91	-100.85	-106.73
45	-35.73	-89.92	-107.17	-112.36
	Stumpage Price $0.15/cu.ft.			
30	17.52	-53.57	-83.32	-97.06
45	29.24	-64.67	-96.70	-107.85
	Stumpage Price $0.20/cu.ft.			
30	86.32	-20.23	-65.79	-87.40
45	94.20	-39.43	-86.24	-103.34

[a]Land expectation values after 90 years of forest management (present worth of future returns). Calculations based upon $100/acre establishment costs and an annual management charge of $2/acre/year.
[b]Anticipated interest rate or return on investment.

land expectation values than age 30 at 4% interest and had a higher total wood production over the 90-year management period being considered. The extra cost associated with carrying the establishment charges for the extra 15 years and the losses that developed from deferring the income from harvest for an additional 15 years, resulted in rotation age 30 being the best at 6, 8 and 10% interest rates.

Rate of Return on Investment

The estimated rate of return on investment for growing red pine as a source of fiber was estimated using $75/acre (intermediate) plantation establishment costs, $0.15/cubic feet ($13.50/cord) stumpage prices and the variable stumpage price of $10/cord that was increased at a rate of 1.5% annually (compounded). The rate of return was determined using the graphic method described earlier for hybrid aspen. Table XL lists the values obtained for red pine (and northern hardwoods).

The rate of return for growing red pine for fiber is expected to range from 3.4 to 5.4%. To obtain a rate of return of approximately 5% requires plantation establishment cost to be no more than $75/acre, stumpage prices to be in excess of $13.50/cord and land prices to be about $50 per acre. Reduction of establishment cost greatly improves the rate of return on investment because of the relatively long rotation ages being used. The total cubic-foot volume production over the 90-year period is expected to be about 9,540 cubic feet for the 30-year rotation and 12,960 cubic feet when managed on a 45-year rotation. These total production figures are approximately one-half of the expected production from hybrid aspen.

TABLE XL

RATE OF RETURN FOR GROWING RED PINE AND NORTHERN HARDWOODS

Rotation, years	Land Values, $/Acre 50	75	100
Red Pine — $0.15/cu.ft. — Stumpage			
30	4.1	3.7	3.4
45	4.1	3.9	3.6
Red Pine — Variable Stumpage[a]			
30	5.3	4.9	4.4
45	5.4	5.1	4.7
Northern Hardwoods — $0.10/cu.ft. Stumpage[d]			
45[b]	<1	<1	<1
45[c]	<1	<1	<1

[a] Stumpage $10 cord and increased at 1-1/2% compounded annually.
[b] Growth rate 75 cu.ft./acre/year.
[c] Growth rate 100 cu.ft./acre/year.
[d] Results the same when variable stumpage ($2.50/cord and increased at 1-1/2%) was used.

NORTHERN HARDWOODS — ECONOMIC ANALYSIS

A third alternative that should be considered is to plant neither red pine nor hybrid aspen but allow the area to regenerate naturally and grow two 45-year rotations of northern hardwoods. Table XXXVI lists the variables considered in comparing this alternative with hybrid aspen and red pine. Four, six, eight, and ten percent interest, several stumpage prices, and two growth rates (75 and 100 cubic feet/acre/year) were used in the economic comparisons. Two growth rates were employed because it was difficult to determine accurately the rate of growth that would be obtained from growing northern hardwoods on the Vilas sandy soils in Northern Wisconsin.

TABLE XLI

LAND EXPECTATION VALUES — NORTHERN HARDWOODS[a]

Stumpage Price, $/cu.ft.	Interest Rate, %[b]			
	4	6	8	10
0.05	-14.70	-20.01	-19.52	-17.65
0.10	19.14	-6.86	-14.07	-15.30
0.15	52.97	-6.29	-8.62	-12.96
0.20	86.81	19.45	-3.17	-10.61
1%/year[c]	-24.46	-24.18	-21.33	-18.44
1-1/2%/year[c]	-6.34	-17.84	-18.84	-17.39

[a]Land expectation values (present worth of future returns, $/acre) after 90 years of forest management. Based upon no establishment costs and growth of 75/cu.ft./acre/year.
[b]Anticipated interest rate or return on investment.
[c]Variable stumpage price starting with $1.90/cord and increasing at 1%/year or starting at $2.50/cord and increasing at 1-1/2%/year.

Tables XLI and XLII summarize the land expectation values obtained for northern hardwoods. Presently, northern hardwood stumpage values average only $1.90/cord. Even at $4.50/cord stumpage and above average growth (100 cubic feet/acre/year) land expectation values for northern hardwoods are negative. When stumpage values are increased to $9.00/cord ($0.10/cubic foot), land expectation values remain negative, except at 4 and 6% expected return on investment. When the rate of return was determined for northern hardwoods, even without establishment cost and using greater than average stumpage prices, rates of return were found to be less than 1% (Table XL). One charge that perhaps could be reduced when considering northern hardwoods is the $2.00/acre annual management charge. Reducing this charge to $1.00 increases the land expectation values shown in Table XLI by $10-16/acre but even this change still fails to increase the rate of return on investment to above 1%.

TABLE XLII

LAND EXPECTATION VALUES — NORTHERN HARDWOODS[a]

Stumpage Price, $/cu.ft.	Interest Rate, %[b]			
	4	6	8	10
0.05	-3.42	-15.62	-17.71	-16.87
0.10	41.69	1.91	-10.44	-13.74
0.15	86.81	19.45	-3.17	-10.61
0.20	131.92	36.98	4.10	-7.48
1%/year[c]	-16.44	-21.19	-20.12	-17.92
1-1/2%/year[c]	7.72	-12.73	-16.79	-16.53

[a] Land expectation values (present worth of future returns, $/acre) after 90 years of forest management. Based upon no establishment costs and growth of 100 cu.ft./acre/year.
[b] Anticipated interest rate or return on investment.
[c] Variable stumpage price starting with $1.90/cord and increasing at 1%/year or starting at $2.50/cord and increasing at 1-1/2%/year.

TABLE XLIII

STUMPAGE PRICES EMPLOYED

Species	Constant Value \$/cu.ft. and (\$/cord)[a]	Variable I Value \$/cu.ft. and (\$/cord)[b]	Variable II Value \$/cu.ft. and (\$/cord)[c]
Hybrid aspen	0.05 (4.50)	--	--
	0.10 (9.00)	--	--
	0.15 (13.50)	--	--
	0.20 (18.00)	--	--
Year			
1975	--	0.039 (3.50)	0.056 (5.00)
1995	--	0.048 (4.32)	0.075 (6.75)
2015	--	0.058 (5.22)	0.102 (9.18)
2035	--	0.071 (6.39)	0.137 (12.33)
2055	--	0.086 (7.74)	0.184 (16.56)
2065	--	0.095 (8.55)	0.214 (19.26)
Red pine	0.05 (4.50)	--	--
	0.10 (9.00)	--	--
	0.15 (13.50)	--	--
	0.20 (18.00)	--	--
1975	--	0.084 (7.60)	0.111 (10.00)
2005	--	0.113 (10.17)	0.174 (15.66)
2020	--	0.131 (11.79)	0.217 (19.53)
2035	--	0.153 (13.77)	0.271 (24.39)
2065	--	0.206 (18.54)	0.424 (38.16)
Northern hardwood	0.05 (4.50)	--	--
	0.10 (9.00)	--	--
	0.15 (13.50)	--	--
	0.20 (18.00)	--	--
1975	--	0.021 (1.89)	0.028 (2.50)
2020	--	0.033 (2.97)	0.055 (4.95)
2065	--	0.051 (4.59)	0.107 (9.63)

[a] Same stumpage value used for each successive rotation, 90 cu.ft./cord.
[b] Stumpage value increased 1%/year compounded, 90 cu.ft./cord.
[c] Stumpage value increased 1-1/2%/year compounded, 90 cu.ft./cord.

TABLE XLIV

LAND EXPECTATION VALUES — HYBRID ASPEN[a]

Rotation Length, years	Interest Rate, %[b] 4	6	8	10
	— Stumpage Price $0.05/cu.ft. —			
8	-29.35	-51.08	-61.54	-67.34
10	21.60	-22.57	-44.08	-55.97
13	68.07	1.49	-30.48	-47.91
15	87.17	10.49	-25.98	-45.72
18	93.67	10.73	-28.04	-48.61
20	90.28	7.65	-31.05	-51.45
	— Stumpage Price $0.10/cu.ft. —			
8	64.83	5.99	-23.11	-39.68
10	166.73	63.02	11.82	-16.95
13	259.68	111.14	39.02	0.82
15	297.88	129.14	48.02	3.56
18	310.88	129.61	43.91	- 2.23
20	304.09	123.45	37.88	- 7.90
	— Stumpage Price $0.15/cu.ft. —			
8	159.02	63.06	15.33	-12.02
10	311.86	148.60	67.72	22.07
13	451.29	220.78	108.52	46.26
15	508.59	247.79	122.02	52.84
18	528.09	248.49	115.85	44.15
20	517.90	239.26	106.81	35.64
	— Stumpage Price $0.20/cu.ft. —			
8	253.20	120.13	53.76	15.64
10	456.99	234.19	123.62	61.09
13	642.29	330.43	178.01	93.35
15	719.30	366.44	196.02	102.12
18	745.30	367.38	187.79	90.53
20	731.72	355.06	175.73	79.19

[a]Land expectation value after 90 years of forest management (present worth of future returns). Calculations based upon $75/acre establishment costs, and an annual management charge of $2/acre/year.

[b]Anticipated interest rate or return on investment.

TABLE XLV

LAND EXPECTATION VALUES — HYBRID ASPEN[a]

Rotation Length, years	Interest Rate, %[b] 4	6	8	10
	— Stumpage Price $0.05/cu.ft. —			
8	-54.35	-76.08	-86.54	-92.34
10	-3.40	-47.57	-69.08	-80.97
13	43.07	-23.51	-55.48	-72.91
15	62.17	-14.51	-50.98	-70.72
18	68.67	-14.27	-53.04	-73.61
20	65.28	-17.35	-56.05	-76.45
	— Stumpage Price $0.10/cu.ft. —			
8	39.83	-19.01	-48.11	-64.68
10	141.73	38.02	-13.18	-41.95
13	234.68	86.14	14.02	-25.82
15	272.88	104.14	23.02	-21.44
18	285.88	104.61	18.91	-27.23
20	279.09	98.45	12.88	-32.90
	— Stumpage Price $0.15/cu.ft. —			
8	134.02	38.06	-9.67	-37.02
10	286.86	123.60	42.72	-2.93
13	426.29	195.78	83.52	21.26
15	483.59	222.79	97.02	27.84
18	503.09	223.49	90.85	19.15
20	492.90	214.26	81.81	10.64
	— Stumpage Price $0.20/cu.ft.			
8	228.20	95.13	28.76	-9.36
10	431.99	209.19	98.62	36.09
13	617.89	305.43	153.01	68.35
15	694.30	341.44	171.02	77.12
18	720.30	342.38	162.79	65.53
20	706.72	330.06	150.73	54.19

[a]Land expectation value after 90 years of forest management (present worth of future returns). Calculations based upon $100/acre establishment costs, and an annual management charge of $2/acre/year.
[b]Anticipated interest rate or return on investment.

TABLE XLVI

LAND EXPECTATION VALUES — HYBRID ASPEN[a]

Rotation Length, years	Interest Rate, %[b] 4	6	8	10
	— Stumpage Price $0.05/cu.ft. —			
8	-79.35	-101.08	-111.54	-117.34
10	-28.40	-72.57	-94.08	-105.97
13	18.07	-48.51	-80.48	-97.91
15	37.17	-39.51	-75.98	-95.72
18	43.67	-39.27	-78.04	-98.61
20	40.28	-42.35	-81.05	-101.45
	— Stumpage Price $0.10/cu.ft. —			
8	14.83	-44.01	-73.11	-89.68
10	116.73	13.02	-38.18	-66.95
13	209.68	61.14	-10.98	-50.82
15	247.88	79.14	-1.98	-46.44
18	260.88	79.61	-6.09	-52.23
20	254.09	73.45	-12.12	-57.90
	— Stumpage Price $0.15/cu.ft. —			
8	109.02	13.06	-34.67	-62.02
10	261.86	98.60	17.72	-27.93
13	401.29	170.79	58.52	-3.74
15	458.59	197.79	72.02	2.84
18	478.09	198.49	65.85	-5.85
20	467.90	189.26	56.81	-14.36
	— Stumpage Price $0.20/cu.ft. —			
8	203.20	70.13	3.76	-34.36
10	406.99	184.19	73.62	11.09
13	592.89	280.43	128.01	43.35
15	669.30	316.44	146.02	52.12
18	695.30	317.38	137.79	40.53
20	681.72	305.06	125.73	29.19

[a]Land expectation value after 90 years of forest management (present worth of future returns). Calculations based upon $125/acre establishment costs, and an annual management charge of $2/acre/year.
[b]Anticipated interest rate or return on investment.

TABLE XLVII

LAND EXPECTATION VALUES — HYBRID ASPEN
VARIABLE STUMPAGE PRICES[a]

Rotation Length, years	Interest Rate, %[b] 4	6	8	10
	Variable Stumpage Price I — $3.50 and 1%[c]			
13	62.34	-20.32	-56.50	-74.90
15	85.46	-10.03	-51.43	-72.35
18	96.13	-7.91	-52.29	-74.34
20	92.65	-10.36	-54.68	-76.64
	Variable Stumpage Price II — $5.00 and 1.5%[c]			
13	216.71	54.88	-13.74	-47.94
15	258.71	72.89	-4.99	-43.51
18	280.24	77.96	-5.47	-46.08
20	273.83	74.34	-8.91	-49.42

[a]Land expectation values after 90 years of forest management (present worth of future returns). Calculations based upon $100/acre establishment costs, and an annual management charge of $2/acre/year.

[b]Anticipated interest rate or return on investment.

[c]Variable stumpage prices calculated by starting with the values given ($/cord) and increasing the price by 1% or 1-1/2%/year (compounded) for the 90 year period.

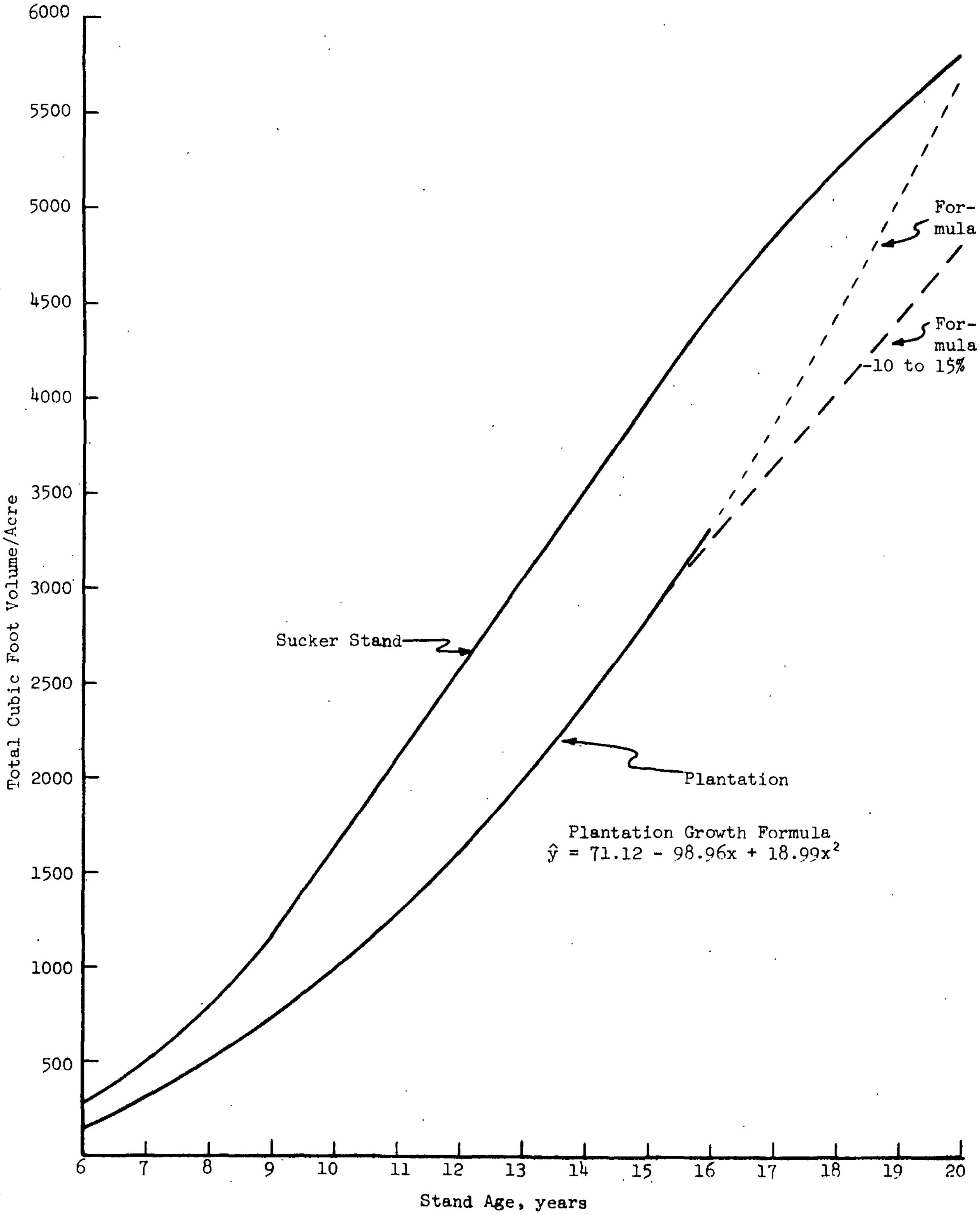

Figure 23. Total Cubic Volume Curves for Triploid Hybrid Aspen. Both Plantation and Sucker Stand Data for Vilas Fine Sand in Northern Wisconsin. Estimated Volumes at Age 18 and 20 Years were Reduced by 10 and 15%, Respectively from Original Least Squares Growth Curves

APPENDIX II

CODE SYSTEM FOR THE POPULUS CROSSING PROGRAM

A code system was devised early in the program to handle the numbering of individual parent trees and crosses. It was necessary to incorporate into the system the ability to identify the species of selected parent trees, the type of cross (parentage) when used for crosses, and the year the trees were selected or the cross was made. The following list gives alphabetically the symbols encountered in the selected tree and crossing system.

To illustrate, T-2-56 = the second _P. tremuloides_ selected in 1956. XT-Ta-14-58 is the 14th cross made in 1958 and the cross involves a _P. tremuloides_ female and a _P. tremula_ male. XCa-G-18-70, S-1 = a selected individual from the 18th cross in 1970 involving a _P. canescens_ female and a _P. grandidentata_ male.

A = _P. alba_	M = _P. maximowiczii_
An = _P. angustifolia_	N = _P. nigra_
B = _P. alba_ var. bolleana	O = open pollinated
Ca = _P. canescens_	S = _P. sieboldii_
D = _P. deltoides_	S-1, S-2, S-3, ... = selected individuals
Da = _P. davidiana_	T = _P. tremuloides_
E = _P. euphratica_	Ta = _P. tremula_
G = _P. grandidentata_	Tc = _P. balsamifera_
Gla = _P. glandulosa_	Tr = _P. trichocarpa_
H = hybrid	Ts = _P. tristis_
I = _P. ilicifolia_	X = cross